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ENZYMES IN THE FERMENTATION INDUSTRIES.*

BY

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Member of the Institute.

I INVITE you to-night for a brief excursion into a chemical field more than others shrouded in humbleness and lack of obviousness. The difficulties with which it teems become, however, far outbalanced by the magnificent vista of large and glorious problems, problems that aim at increasing our present powers over nature ten- and a hundred-fold!

When we use the term " powers of nature " we are inclined to have in mind something grand or forceful, like lightning, the Falls of Niagara, or some other striking phenomenon. But we meet nothing of the kind when getting in touch with the powers wielded by the enzymes. They are more like in the days of Elijah, when we are told that God was not in the torrent nor in the lightning, but in the " still, small voice."

What are these powers? Where are these enzymes? What do they do?

Their very existence has been known only for a few decades. And yet we know to-day that, for instance, on infliction of even a slight wound all the blood would have to run out from our body as water does from a leaky cask if it were not for an enzyme, Thrombase, by which the blood is caused to curdle on contact with

* Presented at the Stated Meeting of the Institute held Wednesday, December 20, 1916.

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air; that we could not make cheese from milk, because likewise minute quantities of another enzyme, chimase (one part of this enzyme to 800,000 parts of milk), must intervene and cause coagulation; that there could be no butter fat either but for the enzyme action; that, in fact, not only all the important bodies on which we subsist, such as sugar, starch, albumin, meat, etc., owe their existence to enzyme intervention; but our using them, assimilating them, is made possible by these agents, to which we likewise are indebted for having such commodities as cotton, flax, wool, silk, leather, wood, etc.

Obviously, as all these articles are derived from the vegetable or animal kingdoms, the enzymes, whatever may be ascribed to them, must be found active in plants and animals.

That is true. All enzymes are produced from and perform most of their marvellous work within the *living cell*. Every attempt to produce an enzyme artificially in the laboratory has so far failed.

But after having followed for a long time and with dogged perseverance in their footsteps, chemical science has now succeeded in isolating enzymes from their living workshops, and has triumphantly compelled them to perform in the glass bottle the work that hitherto had been thought possible only in the living cell.

This flask contains the solution of an enzyme, "zymase," which has the faculty of splitting up sugar into alcohol and carbonic acid. A very few minutes after I now have added some zymase to the sugar solution contained in the second flask, an effervescence caused by the escaping carbonic acid gas will indicate that fermentation has set in, and before long all the sugar solution in the bottle will become dilute alcohol. Thus we see that alcoholic fermentation, which, in the great industries of alcohol, wine, and beer production, depends on the life and continuous propagation of yeast, is here performed away from any organic life by a merely chemical body, the zymase, which had been *isolated* from yeast.

Another striking example we have in an enzyme, catalase, isolated from the liver of the guinea-pig. One grain of this catalase thrown into a bottle containing about two pounds (14,000 grains) of hydrogen peroxide will in a short time split same up into water and into many cubic feet of oxygen.

Or I may mention urease, a urea-splitting enzyme, formed in the body of certain bacteria, and so powerful that the quantity of urea disintegrated per hour amounts to more than 1000 times the weight of their own bodies.

Also, in pepsin we have a case of extracellular enzyme action.

Bring one grain of a highly active pepsin preparation to act upon two pounds of finely-chopped meat, under proper conditions, and this meat, about 14,000 times the quantity of the enzyme employed, becomes liquefied and at the same time entirely converted into other bodies.

From the foregoing it must be clear to you that an astonishingly small amount of the enzyme will suffice for effecting transformation of the body on which it acts, the " substratum," and you may now readily surmise that the enzymes cannot themselves become a part of the new compounds formed.

In fact, if we could protect that one grain of pepsin, for example, from outward influences which tend to undermine its nature and constitution, we could continue and liquefy a thousand times 14,000 parts of meat with the same one part of pepsin, because it is just one of the extraordinary properties of the enzymes that they themselves remain unchanged and without in any way entering into the composition or into the change which they bring about.

In due desire to pay homage to the memory of a great mind, let me here read a passage from the writings of no less a personage than the Swedish chemist, Berzelius, who, far back in 1836, wrote:

" There seems to be a power which, by its mere presence and not by its chemical affinity, has the ability to awaken the affinities slumbering within the elements of bodies, so that in consequence the elements of a compound body may rearrange themselves in different manner; it seems to act after the manner of heat. I am going to use for this power the term ' catalytic power,' and for the decomposition which it brings about the name ' catalysis.' "

Berzelius thus defined such action as enzymes exert about fifty years ahead. The word " enzyme " was introduced by Professor Kühne, but not in the wider sense as it is applied to-day, because it was his belief that the enzymes could effect chemical operations only in the living cell. Now we know that the enzyme *is generated* in the living cell, but that its activity and efficiency are independent from the life process of such cell.

An enzyme is therefore a catalytic body in the sense as defined by Berzelius, but it is of organic origin, and is generated in the living cell, and also active independent of the life of the cell.

Catalytic bodies (enzymes are organic catalysts) of mineral nature hold sway in their different and widely fruitful domain. Wonderful results in this field are shown in our present way of making sulphuric acid by the contact (which means catalytic) process or in the Haber ammonia process, where the elements of ammonia, taken from air and water, are forced into union at high temperatures with the aid of catalysts under great pressure. At present Germany produces over 2,000,000 tons of the ammonia salts.

Here also belongs the hydrogenation of fats, wherein liquid oils are transformed into lard-like bodies for eating purposes or into stearin for candle-making, by causing them to combine with hydrogen gas through the catalytic intervention of metallic nickel.

The enzymes are remarkable in that their action depends on very specific conditions under which alone they can do their work, and that only on specific substances they can act. It has been ascertained that the enzymes act only on substances of definite structural nature, and the group of bodies thus acted upon is of a closely circumscribed character. Emil Fischer has aptly likened this relation of the enzymes to the substratum to a key and lock in which it fits: even a slight alteration of the key renders it useless for opening the lock.

Thus (*A*) in the process of digestion certain enzymes will dissolve and liquefy a certain class of material, which is left entirely untouched by others. Take the proteins contained in meat: they are liquefied (hydrolized) and converted in the stomach into bodies called peptones by the action of pepsin. To become assimilable by the body, however, the peptones have to be much more digested; in fact, they must be digested into all the bodies enumerated in Table I, to which I shall refer later.

If pepsin were left in contact with the peptones ever so long it would never accomplish the required degree of hydrolysis. To do this, an entirely different class of enzymes comes into play.

(*B*) Another characteristic of the enzymes is that for their best action they need specific temperature conditions. They are all destroyed by boiling temperatures, and even when acting at their optimum, which usually lies between 45° and 60° C., such

a deviation as 5° frequently means a great variation in their activity.

(*C*) A point of paramount importance for their action consists in the proper reaction of the medium in which they work, whether acid, alkaline, or neutral. Pepsin, for instance, requires a decidedly acid reaction, such as is always found in the stomach. Amylase, which is contained in the saliva and which digests starch, becomes inoperative in the stomach by this very acid. Trypsin and erepsin, two enzymes contained in the intestines, on the other hand, need an alkaline medium for their work. Trypsin and erepsin continue and complete the protein digestion that was carried on by pepsin, in acid medium, to the peptone stage only.

(*D*) It has been fairly well established that the enzymes are of a colloidal nature. For instance, we can weaken the enzyme solution by violent shaking. They are readily absorbed by other colloids, and, similar to colloids, they can frequently be removed from their solutions by proper filtration through specially-prepared filters.

(*E*) Enzymes have never yet been prepared in chemically pure state, and even the best preparations must be considered very crude. As they originate from living cells, these preparations always have more or less mixed with them, or are " loaded " with, albuminous bodies. Whether the enzyme itself is of an albuminous nature, however, has not yet been definitely decided.

A truly incredible amount of labor and skill has been devoted to improve methods for preparing these valuable enzymes, and usually the substances have to go through a protracted and complicated series of processes. Solvents, like water, dilute salt solutions, very dilute acids, or alkalies, also dissolve most of the impurities which accompany the enzymes.

Glycerine, which does not dissolve albumen, is much in favor. For removing salts dialysis is used, but dialysis, as well as filtration, always tends to weaken the enzymatic efficiency, which further indicates the colloidal nature of the enzymes.

Alcohol and ether are much used in separating the enzymes from the impurities, and fractionated precipitation with ammonium sulphate is used for removing the ballast of albumen. The enzymes are mostly precipitated by heavy metals; they are absorbed by kaolin, talcum, charcoal, albumoses, precipitants, and especially by fibrin. Sometimes, when the resultant products con-

tain sugars or other carbohydrates, these are removed by intense fermentations. I will not go further in this matter, but may say that, in spite of all attempts so far, it has not been possible to get actually pure enzymes in hand.

Likewise, technic for proving and estimating quantitatively enzymatic action is still in its infancy. We determine enzyme values only by the results which their action brings about. For instance, when we wish to establish the activity of a pepsin preparation we have a standard method of allowing the preparation to act for a specific time on egg-albumin and then figure out what quantity of egg-albumin has been dissolved by the action of the pepsin.

The best method of determining pepsin action is the one evolved by Fuld. For his method Fuld used the digestion of edestin, which is a globulin from hemp. This method is so sensitive that if we dissolve one part of an active enzyme pepsin preparation in a million parts of water we can still definitely determine its activity.

I now show you this edestin digestion by pepsin.

Similarly, in determining the activity of amylase, we allow it to act on a starch solution and then determine the quantity of sugars which are formed.

I cannot here further describe all methods which have been proposed to determine the activity of the various enzymes, as for each specific enzyme a special method had to be devised.

Frequently it is necessary to prevent the interference of bacterial action. The addition of toluol has proved to be particularly advantageous, as it prevents bacterial action and only in very slight degree interferes with enzyme action.

Ladies and gentlemen, I beg to confess that I feel a little nervous over having rushed in upon the task of offering you, by way of introduction to this brief lecture, a clear grasp of what enzymes are and what they do.

It would not do much good to recite here, in text-book fashion, even the main classifications and terms under which science now keeps this intricate subject-matter before its eye. I would rather propose, out of the innumerable bodies that are being built up by nature, with the help of enzymes, to select one, follow in the wake of its formation, and to try and pick up a little enzymatic knowledge as we go along.

Enzymes have ever to do with building up or breaking down of the materials whereof the bodies of animals and plants are made.

Processes, where new compounds are obtained by breaking down, are very prevalent. The fermentation industries, where sugar is split up into carbonic acid and alcohol, by the action of the ferment zymase, belong here. But this zymase action is only the last act in quite a series of breaking-down processes, or, as they are termed, " processes of dissimilation " through which beer is obtained from barley.

On the other hand, " processes of assimilation " through constructing or building up activity by enzymes are, of course, often paramount also. We need only to refer to the manner in which bodies like starch, albumin, and fat had been prepared before they were deposited in the barley corn, or as meat fibre or bodyfats in the animal tissue.

One highly noteworthy feature in enzyme activity must be seen in *reversibility of action*. The same enzyme, amylase, by which starch is converted into sugar, will, when occasion arises, form starch grains from dissolved sugar.

Lipase will, in the digestive tract, first segregate fats into fatty acids and glycerine, but later will again unite these constituents to the bodyfats deposited in the tissues.

The particular body on which I now wish to dwell, for the purpose of tracing enzyme action, is albumin, and no more important a subject could we choose.

Life is seated in albumin; the cell in its protoplasm teems with albumin, contains 50, 60, and 70 per cent. of albumin, and debarring the living organism from albumin means death.

Hitherto formation of albumin has been bound up with life processes in bodies of plants and animals. But a better equipment in enzymatic chemistry bids fair for the dawn of synthetic albumin made in chemical factories.

What that would mean becomes obvious when we realize under what conditions we now produce meat. For each 1000 pounds of albumin contained in 6000 pounds of pork we have to raise 25 pigs on about six acres of land. But in a building covering six acres probably as much albumin would be manufactured as on a ranch of 100,000 acres by the present methods.

But examples of similar cases we have close at hand.

In the year 1896 there were in India 1,583,000 acres used for growing indigo, and 8225 concerns were engaged in the making of indigo. By 1913 the number of concerns making indigo had dwindled down to 112. Now consider that the amount of synthetic indigo made in Germany in 1913 was six times the quantity of indigo produced in India in 1896, which means that the old methods of growing natural indigo would have required practically 10,000,000 acres of land to meet the market demands in 1913. This represents three times the acreage grown in potatoes in the United States, or, if you like, all the apple and other fruit orchards and tobacco land put together! And all this indigo was made by the Germans in practically one factory.

If this seems far fetched to you, I assure you it is more plausible than may appear. I show now in this bottle a sample of the so-called mineral yeast. It is to-day produced in Germany by the thousands of tons from ammonia and molasses. This particular sample contains 64 per cent. pure albumin.

What are the building stones used by the enzymes in the constructing of albumin?

Let us try and get an answer to the following very simple proposition:

If, in the case of our own body, the albuminous parts, such as muscle, blood-serum, etc., had all been formed from the food we have eaten (which to a very large part consists of albumin), then an exact knowledge of what became of this food-albumin in the digestive process and of how the digestion products were used up in forming our muscle, etc.—such exact knowledge would certainly enlighten us on the subject of building stones used in forming the albuminous parts of the human body.

It is precisely on this simple line of reasoning that those penetrating minds which have cleared up the laws of albumin formation have set in with their relentless work and carried it to success.

The first changing of food-albumin to simpler bodies is brought about by an enzyme produced in oblong glands imbedded in the mucous membrane which forms the interlining of the stomach. On leaving the glands the enzyme is incomplete, inactive, a "zymogen." Zymogens are, so to speak, rudimentary enzymes, which must come in contact with an "activator" to become real enzymes. Our zymogen enters into intimate combination with hydrochloric acid, of which the stomach juice contains 0.2 to 0.5 per cent.

The enzyme, pepsin, becomes activated thereby and depends always, as I already pointed out, for its action on a decided acid reaction of its medium.

The albumoses, proteoses, and peptones resulting from pepsin action are already water-soluble.

These albumoses, peptones, etc., now in solution, are not by any means completely digested; they are not fit to be assimilated by the liver, the blood, etc. They must be broken up into bodies, such as are enumerated in Table I. Therefore another body enzyme, of a different specificity, trypsin, comes into play. This trypsin, by virtue of its specific adaptation, can act upon these substances and further hydrolize them.

Trypsin, originating from the pancreas gland, is being injected into the digestion mixture in the duodenum. The activity of trypsin would become entirely stopped by the presence of even 0.1 per cent. of hydrochloric acid, because it requires an alkaline medium, and has been found to work best when the alkalinity corresponds to about 0.75 per cent. of sodium carbonate.

There is still another enzyme, exclusively found in the enteric channel, erepsin, specific in a similar way as trypsin, only it is more thorough and brings the cleavage down to the last but one member of our list—to glycocoll.

Now remember what we learned about reversibility in action of enzymes. I told you that the same enzyme, amylase, by which starch is converted into sugar, would, if occasion arises, form starch grains from dissolved sugar. Precisely so here, we find that the albumins disintegrated by the enzymes just mentioned must by the same enzymes be reconstructed.

First (in the gut), to body albumin.

It is most remarkable that this body albumin is specific for the animal in which it takes rise, and even the peptones, after the reconstruction, in no way resemble the original sources.

The body albumin aforesaid has to be broken down again and reconstructed before it can become organ albumin. Also, here we find specific enzymes active; the liver albumin differs from the one found in the kidneys or blood-corpuscles, etc.

In this manner the enzymes are active backward and forward in the body in the albumin construction work. For instance, pepsin is found and is active in this sense in the blood and in the muscles.

The work done on these lines in the body is carried on by a number of specific enzymes, more than twenty in all.

We owe principally to the work of Prof. Emil Fischer, of Berlin, the knowledge basic to our present insight into the constitution of albumin. His first great achievement was the separation of all these many bodies into definite chemical individuals. The task was almost insuperable, but he ultimately succeeded by combining the mixtures of the many digestion products into salts or esters and then inventing a vacuum distillation process through which he could separate the esters, and thus he isolated the pure individual albumin building stones. Then he and his co-workers, especially Professor Abderhalden, of Halle, succeeded in preparing a large number of these identical bodies outside the body, in the chemical laboratory, by purely chemical means, and it has been established that a great many of these artificial albumin bodies can be digested and reconstructed by body enzymes the same as natural ones.

Of these synthetic laboratory products, the "polypeptides," Prof. E. Fisher says:

"From all observations so far made there is an unmistakable similarity between the artificial peptides and the natural peptones. This holds particularly for those synthetic products which contain various amino-acids, and which I shall in future designate as 'mixed polypeptides.' The ordinary reactions of peptones—biuret coloration, precipitation with phosphotungstic acid, hydrolysis with trypsin—hold also for the complex products, and are even more characteristic of their amides. It is indeed true that there are differences in physical properties; thus certain of the artificial polypeptides are comparatively difficultly soluble in water. But this difference loses in significance from the fact that the mixed forms, particularly the optically active combinations, are much more soluble in cold water.

"We should further expect that the introduction of the diamino- and oxyamino-acids into the molecule would further increase the solubility in water and diminish the tendency to crystallization.

"Taken altogether, I am inclined to believe that the acquisition of the artificial polypeptides is the most important step toward the synthesis of the peptones."

Following is a list of individual bodies obtained in albumin cleavage:

TABLE I.

PROTEOSES ALBUMOSES, PEPTONES.

L. Tryptophane.
L. Histidine.
L. Proline.
L. Tyrosine.
L. Phenylalanine.
D. Arginine.
D. Ornithine.
D. Lysine.
L. Asparaginic acid.
L. Cystine.
D. Isoleucine.
L. Leucine.
D. Valine.
Alanine.
Glycocoll.
Urea.

Ammonia.

The five simpler forms from D. isoleucine to glycocoll are the simple amino-acids.

It is probable that the cleavage products become united in and to the albumins in amid-fashion.

The lowest member of the list is urea. Urea is a waste product from the body; it is detached through the kidneys and bladder.

Still lower, below the line, is ammonia.

The animal body is not in the habit of producing this simplest form of combined nitrogen, ammonia; its lowest waste product is urea. However, some plants do; we have examples of certain fungi which secrete ammonia as a waste product. Ammonia escapes from bacterial and fungi cultures often in great quantities.

Likewise, the animal body is entirely incapable of utilizing ammonia for the building up of albumin.

That is reserved exclusively for the plants, which are kept provided with mineral nitrogen (ammonia, nitrates) through their roots.

How do plants build up albumin from mineral nitrogen and carbohydrates, or, as we heard in the case of mineral yeast, from ammonia and sugar?

First, we know that the great function of uniting the elements of water and carbon into starch is performed in the plants by the process of assimilation, through the action of the sun-rays. After this operation, which probably depends on catalytic action, starch grains are observed to appear in the cell. These starch grains are embedded in the protoplasm of the cell in the green leaves.

But starch grains are also found in places where the conditions for their origination absolutely do not exist. A question arises—and it is intimately connected with the activity of the enzymes: How do these starch grains get translocated from the place of their first making or appearing to the various other places in the body of the plant where they are found? They surely could not have pierced the cell walls; that idea is altogether untenable.

One observation about starch grains was early made: namely, that they disappear from the chlorophyll mass of the green plants in which they are embedded when the plants are placed in the dark. Under these conditions, starch grains remain in the chlorophyll-bearing cell only very shortly: they are found to disappear very soon after the conditions for creating new starch grains; that is, the action of light has been removed.

What has become of the starch?

We have in iodine an extremely sensitive reagent for detecting the presence of starch; it is turned deeply blue by iodine. In the part of the cell which is outside the protoplasmic mass starch had never been detected, therefore it could not even penetrate from the protoplasmic mass into the outer layers, let alone wander to remote parts of the plant. Finally, it was found that the cell-juice has the remarkable faculty of dissolving starch and at the same time entirely changing its chemical nature and converting the starch into a sugar.

The change is an enzymatic one, by the action of an enzyme, named diastase, or amylase.

This enzyme amylase is provided by nature wherever the breaking up of starch in this sense has to take place. We find it, for instance, in the saliva where it attacks the starch content of our bread and food; further on, in the stomach, its activity is arrested through the acid reaction which, as I told you, must always prevail where the pepsin, the first albumin digester, has free sway. But later on, in the intestines, the amylase is again found, and it there completes functions of starch resolving quite similar to those we have observed in the protoplasm of the green leaves.

I shall now demonstrate to you here the conversion of starch *in vitro;* show with Fehling's solution that Cu reduction only now sets in.

The great starch containers known to us are tubers, like

potatoes, or the grains, seeds, etc. When converting these starch reserves for the use of the young plants, the enzyme amylase, or diastase, is developed from the very embryo of the young plant.

It bears on our subject of fermentation that practically all studies of these enzymes have been conducted with the enzyme amylase contained in malt extracts, because malt is nothing but barley where incipient growth had been brought about for the very purpose of developing this and also other enzymes.

The sugar or transportable carbohydrate formed from the starch can now, by its soluble nature, penetrate through all cell walls and enter into the protoplasm itself. It is worked up into starch again in many cases where a temporary accumulation of starch is required; and then in that case the iodine reaction is fully restored. It is used as a building stone for making cellulose walls and the whole frame of the plant, bark, leaves, and roots.

Now, for the purpose of our discussion, take it for granted that sugar is found everywhere in the body of the plant—in the stalks, in the leaves, in the roots, in all tissues; and let us now try to understand how this sugar, in conjunction with ammonia salts, may form albumin.

The first conjectures as to how the plants, these original first-hand albumin constructors from the purely mineral salts and sugar (carbohydrates), perform this work which, as I said, could never be brought about in the animal body, was based upon observations of the movements of foods in the young plants. We know that all young plants are provided with a stock of albumin in the seeds; in the course of development of the plant these albumins are acted upon by the enzymes and converted into peptones, albumoses, peptides, and amino-acids in a way entirely analogous to the digestion of albumin in the animal body.

In the mobilization of albumin in the young plant it was early observed that two intermediary organic nitrogen bodies, asparagine and glutamine, were frequently stored up, and it has since been established that they play the highly important rôle of being stored-up building materials for albumin throughout plant life.

The asparagine and glutamine are, as it were, organic ammonias or near-ammonias, somewhat similar to the waste material, urea, which, as we said before, is thrown out by our body. Plants, however, husband their organic ammonia in the form of asparagine and glutamine, and accumulate it for future disposal.

It is highly significant that asparagine and glutamine are soluble, transportable, and as such can travel to where they are needed in the plant.

When it was first shown that, by feeding ammonia salts to young plants, the amount of asparagine and glutamine became increased, we had the first inkling of how the mineral ammonia might be worked in with the organic building material for producing albumin.

Now ammonia or nitrates, by reason of their composition, would not for any length of time alone account for a building up of albumin if the elements of starch or sugar were not also drawn upon. The significant experiments by Saleski in this connection are instructive.

Saleski placed leaves of the sunflower on top of a Knoop nutrient solution (the one used by Professor Knoop, of Leipzig, in his extensive work of cultivating plants in artificial food solutions) to which he had added 4 per cent. of levulose.

The constituents of the Knoop solution are all of a mineral nature, as you may see in the following table:

Koop's Solution in one Litre:

	Grammes
Calcium nitrate	1.30
Potassium nitrate	.33
Prim. potassium phosphate	.33
Potassium chloride	.16
Magnesium sulphate	.33
Ferric chloride	trace.

The increase of albumin which resulted from this experiment must have been taken by the leaves from this stock of nitrates and sugar.

The leaves are the chief laboratories in which albumin is synthesized from nitrogenous substances, but the work also continuously goes on in most other parts, the surface tissues, the roots, etc.

As to what actually takes place in this wonderful process, let me say that probably all mineral nitrogen must be in the form of ammonia, into which nitrates have first to be converted; then follows formation of asparagine and glutamine.

These two important building stones for vegetable albumin

are invariably formed, and to the exclusion of albumin production, when young plants are grown in the dark. But as soon as light is admitted, and thereby starch (and sugar) produced, real albumin is formed, showing that carbohydrates are indispensable.

Thus in the formation of albumin by the plants two main nitrogen-adjustments become disclosed:

1. The rich reserve bodies, asparagine and glutamine (which contain 20 to 21 per cent. nitrogen) become levelled down to albumin (containing 16 per cent. nitrogen) through the entrance of the nitrogen-free carbohydrates (sugar).

2. These reserve bodies (asparagine and glutamine) become synthesized from ammonia by its combining with small amounts of the ever-present amino-acids (which are poor in nitrogen, containing only about 10 per cent.).

Albumin contains much less oxygen than starch or sugar, and a reduction process during the formation of albumin takes place through the intervention of an enzyme, "reductase."

Of the vegetable peptases and amidases that came into play, and especially on enzymatic processes during the first interaction of asparagine and sugar, our knowledge is very meagre.

This extremely brief sketch on the enzymatic albumin formation must suffice; it gives prominence to the following points:

1. Only plants can utilize mineral nitrogen for the building up of albumin. They combine this nitrogen with carbohydrates (sugar), and, as they likewise form the latter from mineral substances (carbonic acid and water), therefore the plants construct albumin from inorganic matter through enzymatic and catalytic activities.

2. Plants do not, like animals, discharge the waste nitrogen in the form of urea, but they husband and deposit such near-ammonia as asparagine and glutamine in places where albumin increase has usually been noted.

3. The building stones for constructing albumen are joined together, the near-ammonias and carbohydrates in plant life, or amino-acids in the animal body, to the higher forms of albumoses or real albumins, by the intervention of enzymes either identical or similar to those which cause the work of dissimilation or breaking up into lower or simpler forms.

In addition to the wandering of the starch and sugar and asparagine, we have now in the plant a wandering of albumin,

which has to furnish the elements for the protoplasm and is everywhere playing a most important part in the development and building up of the body of the plant in seeds and fruits before ripening albumoses are found.

When the plant is fully developed, the movement of all these materials, moved by amylolytic, peptic, and other enzymes, takes a different course. The starch, the albumin, and the fat then produced are transported into the seed, into the tubers, where they act as reserve food material for the young plant.

In the case of plants whose life-cycle is not completed in one season, in perennial plants, a station of rest exists for the winter, at least in the temperate climes, and there in addition reserve food containers in the younger wooded or vegetative parts are filled with starch, albumin, etc., to serve as first food for the development of the young leaves the following spring.

Besides the starch-cleaving and the proteolytic enzymes, there are a large number of other enzymes active in the life of the plant and animal.

Thus "maltase" is indispensable after the conversion of starch into sugar by amylase. The amylase is only able to form maltose as a first step, and this maltose, though transportable, is not fit for being used in many of the cases where the sugar is to be applied in constructive work. Maltase, therefore, which changes the maltose into dextrose, is frequently found accompanying amylase.

Likewise, in our body, it is present in the saliva; always in the gut, especially in the small intestines, in the blood, in the serum and in the pancreatic secretions.

Another important enzyme is invertase, which has the faculty of converting cane-sugar into fructose. It is found in the leaves, roots, stalks, etc., also almost throughout the animal body. The saliva does not contain in this invertase, but it is present in the stomach juice and the pancreas.

Interesting experiments have shown that by injecting cane-sugar into blood this invertase, this enzyme by which cane-sugar can be resolved into absorbable sugar, is being engendered. However, here, as is usual in enzymatic problems, several different invertases exist to meet special substrata conditions.

Without entering further into the great field of these various enzymes, I will say a word about the lipases—the fat enzymes.

The important question, how the fats in the seeds are being converted into food for the young plant, has not been elucidated until recently. A special class of enzymes, the lipases, come into play in the splitting up of the fats, as a first step, into glycerine and fatty acids.

Particularly rich in this lipase is the castor-bean seed, and Cohnstein and his co-workers established, in 1902, methods of utilizing their castor-bean enzyme for industrial purposes by decomposition of fatty oils into fatty acids and glycerine.

The fats are produced in the plant from starch and sugar by a reduction process similar to the utilization of these carbohydrates in the formation of albumin. Probably the breathing of the plants through their leaves plays an important rôle with this fat-forming function of the enzymes.

Of course, many are the functions of the various classes of lipases that exist and are operative in the animal body. They are found in the stomach, in the pancreas, in the animal tissue, and in the blood.

The much-debated question as to how the fats are digested is now pretty well solved on the basis of lipase action throughout. While formerly it was believed that fats were merely finely emulsified and in the form of the very fine emulsions could wander through the membranes of the gut, etc., it has now been proved that lipase in various stages splits up the fats into glycerine and fatty acids which, as such, are then, by a reversible action of the lipase, united and constructed again into real fats.

I will here insert a list of the more important classes of enzymes:

TABLE II.

Animal Proteases.

Pepsin, the principal enzyme of the stomach, where it acts in presence of hydrochloric acid, acts on all natural albumins (proteins), degrading them mainly to the stage of albumoses and peptones); also has functions in gut, liver, blood, etc.

Trypsin likewise resolves natural proteins, but beyond the peptone stage, and even to amino-acids. Found in the pancreatic juice, works in the gut in alkaline medium. Animals can live and digest with stomach extirpated, but die when pancreas is removed. Thus trypsin supplements and may replace pepsin functions. Trypsin becomes activated by the enterokinase.

Erepsin, in the enteric juice, digests peptones to amino-acids.

Chymase, an enzyme in rennet, cleaves casein of milk to paracasein, which then forms the curdle in combination with calcium salts.

Arginase produces urea (and orinthine) from arginin. Prepared from the liver.

Urease, decomposes urea into ammonia and carbonic acid. Produced by bacteria; also found in soya beans.

Amidases split guanin and adenin into ammonia and hydroxic acids.

Nucleases make available the phosphorus compounds from our food. Those compounds become insoluble in and are discharged from the stomach as nucleo-proteins. In the gut the erepsin splits off the protein, which is digested in the ordinary way, while the nuclease, from the remaining nucleic acid, forms and sets free the phosphoric acid.

Nucleases perform similar functions in the vegetable system.

Vegetable Proteases.

Proteinases in plants correspond to the pepsin in the animal body, and break down vegetable albumins as far as albumoses and peptones.

Tryptases correspond to trypsin in the animal body. Proteinases and tryptases are contained in bromelin found in pineapple. A similar enzyme is papain contained in the fruit, leaves, and stems of the papaya tree.

Peptases (erepsases) break down vegetable peptones to amino-acids.

Endotryptase, the powerful proteolytic enzyme of yeast, resolves all the proteins to amino-acids.

Amylases.

Abundantly in leaves, roots, seeds, etc. (oats, barley, corn, potatoes), where starch is hydrolized by them to maltose. In saliva, enteric juice, liver, blood, the body amylases perform similar functions.

Di-Saccharases.

Maltase transforms maltose to dextrose.

Invertase splits saccharose into invert-sugar (fructose).

Lactase breaks up milk-sugar into galactose and dextrose.

Emulsine decomposes amygdaline.

Cellulase and *cytase* attack cellulose and make hemicelluloses available for food.

Zymases

cause splitting up of sugars in alcoholic fermentations.

Phytase,

omnipresent in plants, splits phytine, an important phosphorus-carrying reserve-body, and thereby makes available the phosphorus for building up nucleines and lipoides.

Oxidases

perform activating functions, making possible the important oxidation process within the cell.

Reductases,

in unboiled milk, which therefore discolor methylene-blue, probably coöperate in formation of fats from starch.

Catalases

decompose hydrogen peroxide to water and oxygen. In the blood catalase detaches from the red corpuscles the stored oxygen, which then becomes available (after activation by oxidase) for Oxidation-process within cell.

Lipases.

SPLIT FATS.

Animal lipases act in stomach juice, the enteric juice, in blood, and in the tissues.

The fats are split by lipase and made soluble in water through the agency of bile. Later, by synthetic action of the enteric lipase, the components again unite and actual fats are deposited.

Vegetable or Phyto-Lipases make available the large deposits of fats stored in oil seeds, nuts, etc., for use by the young plant.

Thrombase,

the fibrin-forming enzyme, causing coagulation of the blood, becomes active by admission of air and in presence of small quantities of lime salts. Fresh blood easily flows from the veins, unless the wound is stopped by the fibrin fibres.

The outline given on the nature and activities of enzymes has sufficiently paved the way to discuss their relationship to the special field of the fermentation industries.

The term " fermentation," as a rule, arouses in the layman's mind a vision of bubbling or something boiling—something in motion with evolution of gas. While this holds good in numerous cases, it is by no means a characteristic criterion, and many fermentations exist where none of the resulting bodies come off in the form of gas.

The field of fermentation is very extensive, and I shall confine myself mainly to discuss the enzyme actions in brewing. A good understanding of the many enzymatic processes involved in the production of beer will form an acceptable nucleus around which to acquire knowledge on enzyme actions in other branches of the fermentation industry, such as the production of ethyl alcohol, acetic, lactic, and butyric acids.

The principal raw material in brewing is barley. The ripe barley really represents a well-provisioned storehouse for the young plant, holding starch, sugar, albumins, organic phosphorous compounds, etc., in their proper places, and it is one of the tasks of the brewer that these materials deposited in the grain are, during the malting and mashing process, once more made soluble.

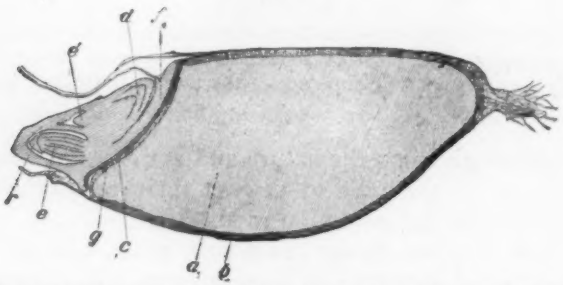
This transformation is accomplished by properly directing the action of the same enzymes through whose instrumentality these substances had originally been transformed, transported, and stored while on the field.

We may well realize, then, the importance of favorable conditions for their original action during growth and ripening to assure a barley which will be a good brewing material.

I call attention here to the importance of soil conditions, to the mode of fertilizing, and the influence of climate on the quality of the barley.

Wet seasons are very damaging, and continuous dry weather

FIG. 1.



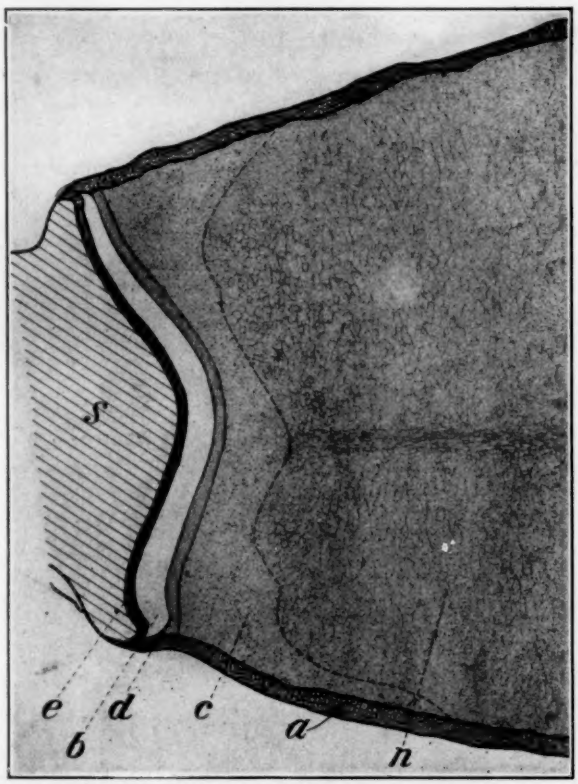
Longitudinal (dorsi-ventral) section of a mature barley grain. *a*, starch endosperm; *b*, aleurone layer; *c*, area of starch endosperm, adjacent to the scutellum, representing the initial stage of the corrosion of the endosperm. This took place at the close of the ripening of the grain. *d-r*, the embryo; *d*, plumule with investing sheath; *e*, primary, and *e'*, secondary, radicles; *f*, scutellum, the surface next to the endosperm covered with the epithelial layer (*g*); *r*, root cap of primary radicle.

for, say, four to six weeks previous to maturing is especially fatal for those enzymatic functions that are accountable for the proper filling of the endosperm and the aleurone layer. Even after harvesting, due time must be allowed to carry ripening operations to a finish, which is usually attained by keeping the barley stored (unthrashed) for some time. Suffice it to say that, in view of quality considerations, good brewing barley frequently commands prices that are 25 per cent. higher than those for other barleys.

In showing you herewith lantern slides of barley, also sections through a barley kernel, I beg to state that I am indebted to the Department of Agriculture, Bureau of Plant Industry, for kind assistance in this matter.

More especially I wish to say that a professional paper by Messrs. Albert Mann, Plant Morphologist, and H. V. Harlan, Agronomist in Charge of Barley Investigations, and entitled "Morphology of the Barley Grain with Reference to its Enzyme-secreting Areas," published April 13, 1915, has been of very con-

FIG. 2.

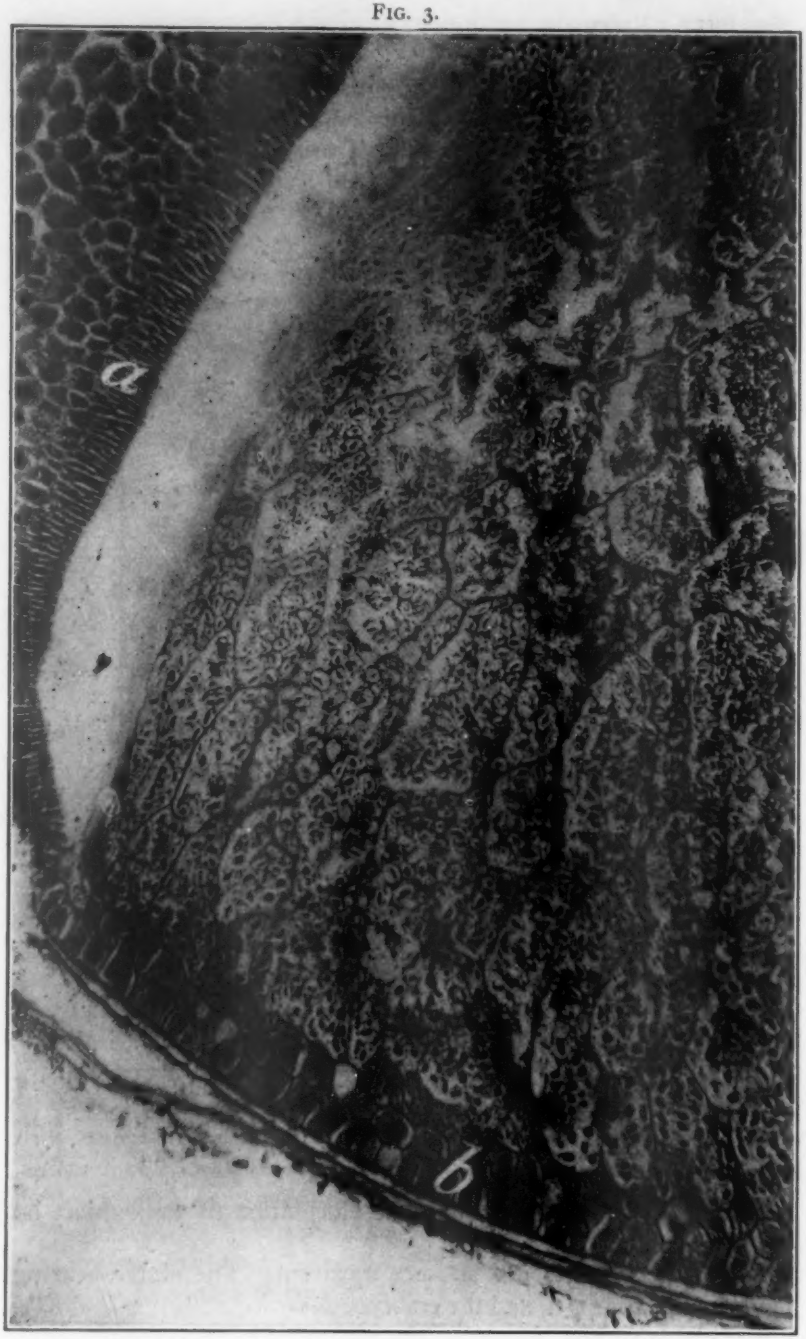


Longitudinal section of barley grain, showing the stage of endosperm conversion at the end of the second day of germination. The starch endosperm is being broken down in the dense areas directly in front of the epithelial layer (*e*) of the scutellum (*s*), and more rapidly in the less dense areas adjacent to the aleurone layer (*a*). *b*, clear fluid area produced during germination; *c*, corroded area of starch endosperm; *n*, normal starch endosperm not yet attacked.

siderable value to me through the elucidation of the subject by their research.

Two main parts are at once apparent: The starch-bearing endosperm, Fig. 1, *a*, and the embryo, *d–r*.

FIG. 3.



Photomicrograph of a part of the scutellum and endosperm of a germinating barley grain. The initial stage of germination is shown. Enzymatic action has begun in front of the epithelial layer (*a*), but not next the aleurone (*b*).

The embryo amounts in weight to about 3 per cent. of the barley corn. You see here, enclosed in a sheath of cellular tissue, the *plumule* (*d*) and the *radicle* (*e, é*), the two principal parts of the still rudimentary future plant. The tissue on the side toward the endosperm, which appears somewhat raised, like a small shield, is called the *scutellum* (*f*). It serves as an intermediary organ for absorbing food, which has to pass through it on its way from the endosperm to the embryo.

Between the scutellum and the endosperm there is, however, one other cell-layer, the very important epithelial layer (*g*). These cells are elongated in form and stand at right angles to the scutellum as well as to the opposite endosperm.

It is now considered probable that the epithelium produces and secretes the enzymes, which from there make their way into the endosperm, where they liquefy and make available the stored-up reserve materials which the embryo needs for respiration and growth.

The whole endosperm is surrounded by, and enclosed in, the aleurone layer (*b*). When the kernel grows the aleurone layer consists in the beginning of a single layer of strong cubical cells, which grow to three as the endosperm-mass develops. This aleurone layer, which contains large quantities of histological albumin, is not affected in malting, and is found intact even in the residuary grains from the brewer's mash-tub.

Figs. 2 and 3 show additional detail; Fig. 4, a whole barley grain from the outside.

Another class of albumin is found in large amounts in the layer beneath the aleurone layer, and this albumin, which does undergo enzymatic changes during the malting and mashing operations, is called the physiological or reserve albumin.

The starch-cells constitute the bulk of the endosperm. Most of them show much compression, and their centres are distorted, except the cells bordering on the aleurone layer, which are the last in the endosperm tissue to fill with starch and are more spongy and not so densely packed.

The epithelium cells, from which, as we have stated, probably emanate the various enzymes, cytase, amylase, protease, phytase, etc., will during germination grow to four times their original

NOTE.—The illustrations, Figs. 1 to 4, are from Mann and Harlan's "Morphology of the Barley Grain," Bul. 183, U. S. Department of Agriculture.

length and, according to Mann and Harlan, also show marked differences in their protoplasmic contents. At times they appear to be heavily charged at the ends; then these plasmatic lumps again disappear and are periodically formed anew and disappear again.

I shall now briefly describe the principal practical brewery operations, and refer more especially to the enzyme actions taking place.

MALTING PROCESS.

The barley is steeped in water for about 48 hours, during which time it absorbs 40 to 50 per cent. of its own weight of water. Then the steeped barley is put in heaps several feet high. Before long the process of germination begins and a rise of temperature sets in.

As germination progresses, the heap is continually spread out on the floors and turned over from time to time to provide proper ventilation, and the germination is allowed to proceed until the acrospire (the young plant) has grown to about three-fourths of the full length of the kernel.

This is the old process and is called "floor malting."

In the newer process, called "pneumatic malting," the germination of the barley is done either in drums or in compartments (Saladin process) where the germinating barley is loosened and turned over by machinery and temperatures and moisture content of the air are automatically regulated.

With either method the germination process requires approximately one week.

I herewith show you samples of growing barley in different stages of the process:

A. Barley.
B. After three days' germination.
C. After seven days' germination.
D. Finished malt.

Let us now consider what changes have taken place in the barley during malting. Physiological activities began from the first moment of its contact with the steeping water. Respiration was at first sustained by the small amount of sugar which the barley contained and which became dissolved through steeping. The soluble food material was soon used up and the embryo needed further food for its development; it needed carbohydrates,

nitrogenous and mineral substances, which all had to be provided in water-soluble and diffusible form.

As we know, the reserve materials contained in the endosperm, however, are practically all in the form of insoluble compounds, starch, albumin, and organic phosphor compounds. To make these available, the whole machinery of enzyme secretion is set into motion by the embryo, and our barley corn becomes converted from a storehouse into an intricate laboratory.

FIG. 4.

A high-grade barley grain with the glumes removed to show the embryo with its collar-like scutellum (*s*). The inner envelopes have been removed from the upper part of the grain.

To do this work of making available and degrading the reserve material, the embryo secretes a number of enzymes which accomplish this task with the greatest ease. Among those enzymes to do this work we may mention oxidase, cytase, amylase, protease, and phytase.

The formation of amylase during germination has been made a particular subject of study, and I refer here to the work of Brown and Morris, Gruess, and Mann and Harlan.

Mann and Harlan showed that the first change observable

during germination begins in the narrow layer of empty cells between the epithelial layer and the endosperm proper. The process soon affects the starch-bearing cells of the endosperm and gradually permeates the whole grain. Those layers of starch which are beneath the aleurone wall are first attacked, and this is responsible for the former view that the amylase was secreted from the aleurone layer. The real reason for this phenomenon, however, is the fact already mentioned, that the peripheral starch-cells are younger and less densely filled with starch, therefore more readily succumb to the enzymatic action.

The conversion of starch could not have been performed unless the cytase, a special enzyme, had previously acted upon the cell walls of the starch-cells.

By action of the cytase, these cell walls swell, become pitted and corroded; they, however, never entirely disappear.

The presence of two proteases has been established, and they attack and partly dissolve and degrade the physiological albumin.

The enzyme phytase performs the work of mineralizing organic phosphorus compounds, which, as we shall presently see, are also of greatest importance during the fermenting phase, for it has been established that the yeast enzyme, zymase, which performs the real fermentation work, can only do so in the presence and in combination with the alkaline phosphates.

Due to the action of these various enzymes, the whole physical condition of the barley is also completely changed; its original glassiness disappears, and the endosperm becomes floury and friable and in a condition to be readily acted upon at a later stage (that is, during the mashing process), which we will discuss presently.

During this germination, which usually lasts about a week, large amounts of carbonic acid are given off.

The oxygen, in order to become available for the breathing, must be activated. This is performed through the intervention of a special class of enzymes belonging to the group of the oxidases. If sufficient air is not available, the young plant will for a while provide its oxygen by decomposing its own substance; but the products that arise from such intermolecular breathing are poisonous and finally kill the young plant itself.

(To be concluded in June issue.)

CHEMISTRY AND AMERICAN INDUSTRY.*

BY

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THE fact that chemistry is the real basis of human industry has been better advertised during the past two years and is now more fully understood by the general public than ever before in the history of the human race. Long before the word "chemistry" existed, prehistoric man began to practise the art, when he discovered, some time in the dim past, that the fires he built against the walls of cliff and cave changed the nature of the earthy materials with which he was familiar. Ceramics and metallurgy are the oldest of human industries, and none are more dependent upon obscure chemical actions and reactions. Although ancient as a practised art, chemistry as a science is no older than our own Declaration of Independence, and, indeed, may be said to have germinated from its seed in the bloody soil and under the murky clouds of war and revolution. Lavoisier, the great Frenchman, the father of the modern science of chemistry, was guillotined by the angry mob at the time of the Terror, but, like John Brown's, his soul goes marching on. It is curious that it should be reserved for this second time of Terror to give a new impetus to this most basic of all the arts and sciences. If war was destined to bring all evil and no good in its train, optimism would be impossible and race suicide excusable.

If American industry is to learn and benefit from the lessons of the past three years, it is necessary that the American people should realize more keenly and with a more active interest some of the facts that this paper will attempt to set forth. Either directly or indirectly, chemistry as applied to industry affects the conditions and well-being of every American home. The clothes we wear, the food we eat, the utensils we handle and prepare it with, the materials of construction with which we are housed or transported from place to place, the medicines which we depend upon in the struggle with disease and death, are all, in one way or another, dependent upon strictly chemical industries. It is

* Presented at the stated meeting of the Institute held Wednesday, March 21, 1917.

chemistry that has made it possible to produce iron and steel on the enormous tonnage scale that makes modern civilization possible. It is chemistry that teaches us to make from ill-smelling, viscid coal-tar, the by-product of the gas and coke industry, thousands of beautiful colors and dyes, medicinals, and high explosives. The red silk parasol of a summer beach and the red wound of war have a common origin in that black, sticky mass. It is chemistry that has developed that wonderful structural material, Portland cement, that enables man to mould his building stone in the place he wants it so that in a few hours it attains the same condition of solidity and durability possessed by rock which Nature laid down and solidified in the course of geological epochs. Truly man takes upon himself the attributes of a creator when he learns to properly apply the principles and science of chemistry to the materials which surround him.

Our country, with its vast natural resources in coal, ores, and lumber, and with its extraordinarily diversified products of agriculture, has had special need to apply science to industry. Much has been done, but at best, except possibly in some exclusive lines, we have not heretofore kept pace with Europe in the application of chemistry to industry. It will do no harm and may do good to state very clearly that the apathy and careless ignorance of our people in regard to applied science in general have constituted a great hindrance to our progress along certain most important lines. George Washington, with the wisdom which was his, foresaw this national tendency, and his state papers constantly urged upon the Congress and the people that state of preparedness which depends upon the application of science to the arts of peace and war. Nevertheless, the great European war, with its consequent embargoes, found us terribly deficient in any preparation for an event that a wise government and people might have foreseen and anticipated as at least a dangerous possibility. And so for a long time after the outbreak of war there was a great scurrying about in our industrial ant hill, and great consternation over the question as to what some of our important enterprises were going to do without supplies of certain essential raw materials necessary to the arts, industries, and to the national defense. And now, as these words are written, with the world war threatening to engulf us also, great mills and factories in many sections of the country are shutting down and banking their

fires for the lack of cars to move fuel to the furnaces. It would seem that a wise government should recognize that in order to be an efficient people in peace or war the wheels of industry must be kept moving. The much-debated question of belated battleships that should have been building years ago is serious enough, but crippled industry is far more ominous, and its relief is worthy of the study and the helpful coöperation of government. The attitude of the great mass of the American people as expressed through its government has, however, for years past been one of passive indifference when it has not been one of active hostility, not only to the great chemical industries but to the railways which feed them and distribute their products.

The past two years have seen a better appreciation by the layman and the press as to the place chemistry really occupies in the national life, but even now people who are not technically trained do not realize that certain minor constituents which enter into the production of the necessities of life and national defense are quite as important factors in our political and economic salvation as the main-line raw materials. With all the wood, wool, cotton, coal, copper, and iron in the world in our possession, our mills and factories would stand idle if certain needed chemicals, whose very names are often unfamiliar to the man in the street, were unobtainable. Dr. George D. Rosengarten, a member of this Institute, in a presidential address before the American Institute of Chemical Engineers, has strikingly pointed out that had it not been for the discovery of sulphur in Louisiana and the economical method of mining it, devised by a famous chemist, in 1891, the balance of trade would not now be on our side to-day, and untold millions of dollars that have come to this country would have stayed at home or have gone elsewhere. How many people realize that the quantity of sulphuric acid consumed by a nation is a measure of its industry, that a large part of the great iron and steel mills would have to shut down for lack of it, while not a pound of powder to serve the guns could be made without this corrosive liquid?

As an interesting instance of the influence of more or less obscure minerals and chemicals on the destiny of nations, I wish to refer to a speech before the Parliament made by the British Minister of Munitions, the Rt. Hon. Edwin Montague, on August 15, 1916. In describing one morning's work, he recites how he

began his day completing arrangements for the transport from near the Arctic Circle to a neutral country of a mineral, the name of which was unknown to him, but which he understood was the limiting factor in the output of certain indispensable munitions. He next took up the question as to whether a certain railway must be constructed in a remote part of India to obtain strange supplies of material wanted for munitions. Next came a discussion and decision as to the allocation of a certain chemical, very limited in quantity, to meet the competing needs of the army, the navy, and the air service. After this, a conference on certain contracts in America valued at over £10,000,000 sterling. Next, an inspection of new inventions in artificial legs. And so on and on through a hundred-and-one topics which, as the Minister says, must confront any body of men who spend their whole days watching curves which ought always to go up and figures which ought always to swell; confronted always with the cry, "More, more, more!" and "Better, better, better!"

Returning to our own problems, let me recite a few cases of industrial unpreparedness that come prominently to mind at this time.

Before men can fight they must be fed. How few people realize that the feeding of a great people, either in peace or war, is largely a metallurgical problem with which the steel industry is primarily concerned! Not only much of our harvest yields but also the major portion of our annual sea food must be packed and preserved in tinned cans. A "tin can" is really made of sheet steel covered over with a thin wash of tin, and no other metal known can be used as a substitute. In spite of the fact that a tinned can carries only a small weight of tin, so great is our canning industry that in 1914 we imported from overseas 52,919 tons of this metal, valued at about $33,000,000. Tin is not found in paying quantities in the United States, and in 1914 only 157 tons were produced in Alaska. The principal world source is in the East Indies and the Malay States, and is controlled by Great Britain. Tin ore is also found in Bolivia and is at present being imported and smelted in New Jersey, but thus far tin from this source is only a small factor in a great industry. As has been shown, the question of our tin supply is a most important factor in our food supply. This subject, according to the daily press, is now receiving the anxious attention of our government. Had

this been the case three years ago the probabilities are that any present and pressing emergency could have been forestalled.

Much of the world's supply of iron ore and coal lies right at our hand. According to the general idea, all that is necessary is to bring these things together in order to produce steel, the main prop of nations, whether in peace or war. But, among other things, steel cannot be manufactured without manganese, although this element is only a minor constituent rarely present in steel to the extent of more than one-half of one per cent. Shortly after the outbreak of the war ferromanganese was so scarce and so difficult to obtain that some steel manufacturers become panicky and the price is said to have reached the phenomenal figure of $1000 a ton for a material which in 1913 sold for about $60 and which is now quoted at $300. In the decade from 1903 to 1914 we imported from overseas over 1,300,000 tons, or about $51,000,000 worth, of this essential of our greatest industry. In the report of the Mineral Resources of the United States for 1913, published by the U. S. Geological Survey, we read that "Manganese ore mining in this country can hardly be said to have been a profitable industry. The causes are probably numerous, some of the more common being failure to explore the deposits sufficiently in advance of installation of washing equipment, lack of familiarity with the common features of the deposits in general, and possibly lack of high degree of technical skill on the part of operators."

It is all very well to accept praise where praise is due for the phenomenal growth of American industry, but none the less the government report above quoted is fairly indicative of some of the careless, slipshod methods in vogue in this country. Four years have elapsed, and a prominent New York daily paper of February 15, 1917, announces in headlines: "English Makers of Manganese Withdraw from the Market. Steel Companies Alarmed by the Serious Outlook for Ferromanganese are Feverishly Buying Manganese at Rapidly Advancing Prices."

As a matter of fact, there is ferromanganese enough in this country at present to supply our steel industry on a hand-to-mouth basis, but it is difficult to prophesy what the immediate economic effects of a stoppage of this important substance would be, especially in the event of actual warfare.

The same daily paper quoted above contains the report of the

leading company of a great American chemical industry—one on which the American people would have to very largely depend for the national defence in case of war. From this report I take one brief paragraph, as pertinent to the subjects I am here discussing:

> "It is regrettable that the United States Government has made our stockholders victims of excessive taxation. Under the corporation tax and ammunition tax laws, the tax levied against our company for the year 1916 alone will result in our paying to the United States Government an amount equal to the entire profit made on sales of military powders to the United States Government by this company and its predecessors since the inception of the industry about twenty years ago. To state it another way, the tax levied against our company for 1916 under these laws will aggregate an amount equal to 170 per cent. of our entire net earnings for the year 1912, in which year we had the largest earnings in the history of the company prior to the war."

As this paper is being written the United States Government is pleading before the Supreme Court for a dissolution of the great Steel Corporation, which ought to be one of our greatest assets, whether in peace or war. Where the governments of other great nations offer coöperation and even financial assistance to the great industries on which their national safety depends, our government sees fit to oppose obstacles and discourage growth by excessive taxation. What the effect of such policies will be, should we ever be forced into a condition more serious than a mere state of war or armed neutrality, is a question which we can only hope will not have to be put to test by the final and awful eventuality.

Although awake at last, Great Britain has suffered from the same national complaint, and Dr. Alexander Findlay, in his book on "Chemistry in the Service of Man," has used words which apply quite as well to America as they do to England. They will bear repetition:

> "The crisis through which this and other European countries are now passing has brought home to us how greatly we, as a nation, have hitherto failed to recog-

nize the intimate and vital dependence of our social and national prosperity on a knowledge and appreciation of the facts and principles of science, and not least of chemistry, and on their application in industry. All the industries of the country on which not only the comfort, but even the life of the people depends—the great manufacturing industries and agriculture, the greatest industry of all—claim tribute of chemistry. And yet we, as a nation, have done much less than the responsibilities of our civilization demanded to promote and encourage the development of chemical knowledge; we have even, indeed, largely failed to avail ourselves of that tribute which science is so willing to pay. To the work of laying the foundation of pure science, on which the superstructure of successful industrial achievement must be raised, British chemists have, according to the measure of their numbers, contributed an honourable share; but the people as a whole, being ignorant of science, have mistrusted and looked askance at those who alone could enlarge the scope of their industries and increase the efficiency of their labours. And so we have witnessed in the past an appalling and needless waste of our national resources, and in too many cases industries have languished and succumbed, or, even when born under conditions of great promise, have remained dwarfed and stunted in growth. In 1862 the German chemist, Hofmann, at that time a professor of chemistry in London, could utter the prophecy: 'England will, beyond question, at no distant day, become herself the greatest colour-producing country in the world; nay, by the strangest of revolutions, she may, ere long, send her coal-derived blues to indigo-growing India, her tar-distilled crimsons to cochineal-producing Mexico, and her fossil substitutes for quercitron and safflower to China, Japan, and the other countries whence these articles are now derived.' But alas! that prophecy has not yet been fulfilled, and the industry of synthetic dyes, an industry which above all others depends on the fostering and encouragement of chemical research and on the highest scientific efficiency, has

found a home elsewhere amid more congenial surroundings.

"But there are now welcome signs that the country is awakening to a sense of past deficiencies, and already the government has taken a first short step in the direction of encouraging and assisting scientific and industrial research. But if the national effort is really to become effective and to exert a lasting influence, something more is necessary, something which is, perhaps, more difficult of achievement than governmental aid. The mental outlook and the attitude of the people as a whole towards science must be changed, and the scientific habit and a spirit of trust in science must be cultivated; and we must also attract in much larger numbers into the ranks of scientific workers men of equal mental calibre to, and capable of taking the same wide outlook as, those who are at present attracted into the higher ranks of the legal profession or into the civil services. Science stands for efficiency *in all the activities of life*, and the neglect of science spells waste and industrial decay. It is for the country to choose the path which it will follow."

A year ago I published a paper in the JOURNAL of this Institute on "The Rôle of Chemistry in the War." This paper, which was reprinted by the U. S. Senate as Senate Document No. 340, attempted, among other things, to set forth the great importance of studying methods of fixing atmospheric nitrogen for the production of fertilizers and high explosives. In that paper the effort was made to explain in simple language the absolute dependence of our people on an adequate supply of fixed nitrogen, and the danger that would ensue if war or embargo should interfere with the importation of fixed nitrogen from the nitrate beds of Chile. The air we breathe consists of nearly four-fifths of nitrogen gas, or equivalent to a weight of 33,880 tons upon every acre of land. The land needs nitrogen for the production of crops, but, except through the agency of bacteria which, curiously enough, are associated only with the root systems of beans, peas, and clovers, vegetation cannot make use of the free nitrogen of the air. Also, before it can be used for making high explosives, nitrogen must be fixed to some other element. Once

thus fixed, it makes little difference to the chemist what it is joined with, as he can by one method or another manipulate it to any end product desired. Nitrogen may appear combined with other elements as a simple fertilizer for your lawn; as a deadly, treacherous explosive, an ounce of which is sufficient to wreck a building or a battleship. It may take the form of a deadly poison, cyanide, which is used to extract gold from its ores. It may be a principal constituent of a beautiful dye or a beneficent medicine. It is a constituent of the wool we wear upon our backs, of the leather on our feet. Joined with oxygen, it forms the corrosive nitric acid which dissolves nearly all metals; joined with hydrogen, it forms the familiar pungent alkali, ammonia, which neutralizes all acids. Fixed nitrogen in the form of protein makes the principal strength and value of the food we eat. Animals having absorbed it in part excrete the remainder in a different combination, and the manure goes back to the land to be used in part again. But there is always waste, and a large portion gets free and escapes back into the atmospheric ocean from which it originally came, hence the call upon the chemist to devise methods for its fixation.

During the past year there has been much discussion and agitation over the question of nitrogen fixation. Many of the great steel and smelting companies have invested large sums of money in the installation of by-product coke ovens. One of the by-products of coke making is ammonia, and it is claimed that the fixed nitrogen from this source alone would supply all the reasonable needs of the nation. Large quantities of ammonia are, however, needed for the cooling and refrigeration of the enormous meat supplies of the world, while the chemical methods used in changing ammonia to the much-needed nitric acid state of fixation present certain difficult problems which have not yet been fully worked out in this country.

By a method which is worked on a large scale at Niagara Falls, Canada, nitrogen is fixed to carbon to form a chemical compound known as cyanamide. If carbon in the form of ground coal or coke is mixed with lime and heated in an electric furnace, a carbide is formed. If air nitrogen is conducted into this substance in another furnace, the mass is converted into calcium cyanamide ($CaCN_2$), an excellent fertilizer under certain conditions. Treated with steam, this compound yields ammonia.

Nitrogen can also be fixed by passing huge electric arcs or sparks through air which is conducted between terminals enclosed in furnaces of a special type. Congress has within the past year appropriated $20,000,000 for the installation of a government nitrogen fixation process, but no announcement has yet been made as to what method the government's advisers intend to select, and it is exceedingly doubtful whether the appropriation will be large enough for the purpose, or whether, under our American conditions, such a government plant could be operated except as a losing venture.

Recently an American scientist, Prof. J. E. Bucher, of Brown University, has announced a new process by which sodium carbonate, the chemical familiar to every household under the name of washing soda, is mixed with finely-ground iron ore and coke dust and the mixture heated in a current of air to a moderate temperature. Nitrogen is fixed in the form of the poisonous sodium cyanide (NaCN). As has been pointed out, nitrogen once fixed lends itself to the chemist with great adaptation. From cyanide, ammonia and an astonishing number of useful chemicals, both of an organic and inorganic nature, can be made. The chemical changes which are proposed are too complicated for discussion in this paper, but it is interesting to note that one of the compounds which can be readily synthesized by this process is urea, a metabolic product of animal life. As urea contains 46 per cent. of fixed nitrogen and is soluble, it should be and is an intensive fertilizer. Its cost heretofore has alone excluded it from use for this purpose. Bucher's researches, which have persisted through a number of years, have been carried out with fascinating simplicity and ingenuity. It is as yet too soon to venture a prediction as to the economic and commercial success of this new method of attacking the nitrogen fixation problem, but while awaiting the verdict of the future we may be permitted to hope that this fine example of persistent American research will prove to be at least one useful way of tapping the inexhaustible treasure of the air.

The potash situation in this country since the war has been an interesting one, and, while the scarcity of this important chemical has crippled some American industries, chemists in some lines have been stimulated to work out methods of getting on without it. Before the war certain grades of glass, such, for instance, as are

used for making electric-light bulbs, were potash glass. Now it is quite certain that better glass is being made in America than ever before, in spite of the potash famine. Potash, however, like fixed nitrogen, is a necessary plant food, and intensive agriculture cannot get on indefinitely without it, unless potash or the lack of it is to become a very important factor in the much-discussed high cost of living. As sold on the basis of fertilizer value before the war, potash was worth about $34 per ton. It is now quoted nominally at $400, though, owing to its practical absence from the market, sales are rare occurrences. It is perhaps needless to repeat here that practically all the normal world's supply of potash has heretofore come from mines controlled by Germany. We have unlimited quantities of potash locked up in an insoluble form in our feldspathic rocks, but it costs more than $30 per ton to get it out, so that fear of German competition after the war has prevented capital from developing the processes that American chemists have worked out for treating these potash ores. A certain quantity of potash is collected as a by-product in the manufacture of some few types of cement, and to a certain extent it is being extracted from sea-weed on the Pacific coast and from a potash-bearing mineral known as alunite, which is found in Utah. It is also, with a good deal of trouble, extracted from the brines of some of our western salt lakes, and from hardwood ashes. In all, our domestic production from all sources in 1916 was less than 9000 tons, while our yearly need at present is probably greatly in excess of 300,000 tons. The fact remains that up to date there is no potash industry in America at all commensurate with our present or future needs.

The chemistry of coal-tar has been tremendously stimulated in America within the last three years, and the manufacture of many beautiful dyes and useful chemicals and medicinals from this source, which used to come exclusively from Germany, is now firmly established in this country. The dyestuff situation has been much discussed in the daily press, and many wrong impressions have been disseminated in regard to it, in spite of the fact that a number of papers containing the simple truth have been published by chemical experts. I touch but briefly on this phase of chemistry in American industry, as the subject is one that can be discussed far better by others and is worthy of a paper by itself.

Dr. J. M. Mathews, addressing a section of the American Chemical Society, recently made some comments on the public attitude towards applied chemistry which I shall take the liberty of repeating at this place, as in a way it serves to introduce the next phase of chemical industry which I have selected to discuss in this paper. Dr. Mathews said:

> "The past two years, I think, have seen a better appreciation by the layman and the press as to just what the chemist is and what his profession consists of and can accomplish. There is still that idea, however, prevailing that chemistry is a hodge-podge of mysterious secrets, the discovery of which is made by accidental and haphazard methods. The popular mind has evidently not yet progressed beyond the age of the alchemist. In things chemical the public has still the innocently receptive mind of a child; it will accept as gospel truth the most absurd and illogical statements of supposed discoveries. Some so-called chemist announces the remarkable discovery that by the addition of a few drops of a mysterious green liquid to water he creates a perfect substitute for gasoline for use in automobiles. The daily press devotes column after column to this truly remarkable process, and the public evidences the keenest and most serious interest. The thing could not be more absurd than if a physician announced that he had discovered that he could make new legs grow where those members had been amputated, by rubbing a decoction of hen's teeth on the parts affected. I hardly believe either the press or the public would take this latter announcement seriously, and any editor would consider it too foolish to be printed. And yet how often have we been regaled at the breakfast table with glaring headlines announcing with all seriousness that Dr. So-and-So, a celebrated chemist (whom none of us had ever heard of before), had just discovered the *secret* of the German dyes."

The war, as well as the enormous domestic growth in automobile traffic, with the inevitable rise in the price of motor fuel, has naturally stimulated the study by American chemists and

engineers of the whole motor fuel question. There are a number of different lines along which this problem can be attacked. Benzine, or benzol, one of the many by-products of coal-tar distillation already referred to, may some day be cheap enough in this country to use as a motor fuel, either alone or mixed with gasoline. Again, engines can be designed to burn denatured or industrial alcohol, and chemistry has already devised practical methods for making so-called grain or ethyl alcohol out of sawdust and other woody waste material. This presents an interesting possibility from the conservation standpoint, because when we use up petroleum or coal we have consumed just that much of a natural resource that will never come back to us again. But alcohol can be made from crops that are planted and thus renewed from year to year. Since alcohol can also be made from any starchy plant, it would not be impossible to contemplate at some future time growing our motor fuel each year, just as we now grow potatoes and corn. Moreover, in the making of alcohol, bacteria and other microscopic organisms are put to work in the service of man, a fascinating source of energy that will probably be exploited by our posterity to a much greater degree than it has up to the present time.

Whatever may be the final solution of the motor fuel question, it seems quite certain that for some time to come the natural petroleum deposits of the earth will continue to furnish the bulk of our liquid fuels. In addition to the large petroleum resources of North America, South American sources have not yet been fully explored, while the extraordinary petroleum wells in the Mexican field promise a practically inexhaustible supply of raw material.

The Mexican oil fields, however, though developed and owned by American capital, are left open and unpoliced by our government, ready to be grabbed by any foreign government or even any group of bandits strong enough to take possession. Such possession would constitute a very considerable balance of power in world affairs to-day, and the recapture would call for an untold expenditure of blood and treasure, perhaps to no purpose, as a retreating enemy can destroy oil wells, tanks, and pipe lines so that years must pass before they can again become available. This danger has been emphasized by the terrible destruction in the oil fields of Roumania and Galicia.

It is a fact not generally known that a great many of the

large petroleum deposits of the world contain little or no light-boiling constituents which we call gasoline or naphtha and which are known in Europe as petrol. The petroleums of the mid-continental field of the United States yield from eight to twelve or even fifteen per cent. of natural gasoline, but some of the California, Texas, and all of the Mexican petroleums contain very little of the lighter boiling fractions suitable for motor fuels. Now, to use an analogy, if we have large, heavy pieces of stone or other solid materials which we wish to make more conformable for certain purposes, we usually crack up the large pieces into smaller ones and then screen the pieces into lots of more or less approximately even size, and sometimes we wash the resulting materials to remove adherent dust and impurities. Now, this is precisely analogous to what chemistry is doing to heavy hydrocarbon molecules, of which natural petroleum, as it exudes from below the earth's surface, is constituted. By a process known as fractional distillation under pressure the heavy molecules vaporized and put into rapid movement by the heat might almost be said to crack themselves into pieces by violently colliding with each other and with the walls of the containing vessel. This is the process actually known as "cracking," by which the percentage of gasoline is artificially increased so that we obtain a greater yield than Nature had originally provided in the crude oil. But just as in our analogy the screens separated the cracked stone into various sizes, the distillation separates the oil into fractions, the dust of which appears as a permanent gas which cannot be liquefied and shipped, but must be locally burned as fuel or piped away. The next lot of fine screenings, say of sand-grain dimensions, might represent the ethereal liquids known as naphthas, petroleum ethers, or rigolines. Next come the analogues of the fine-grained gravel sizes used for gasoline motor fuels, next the coarser gravel size representing the kerosenes, then the still larger sortings corresponding to the lubricating oils, and finally the larger lumps—the axle greases, asphaltic pitches, and solid paraffins.

The fuel oils on which the navies of the world are rapidly coming to depend may be considered as a mixture of all these fractions after the lightest or finest have been removed and the heaviest and coarsest left behind.

Now, no analogy is perfect, and the one used above must not

be pushed too far, but it serves a very good purpose in making clear to the general reader the answer to a number of questions which are constantly being asked.

If the supply of crude oil is so abundant and if the cracking process is efficient, why should not the supply of gasoline keep pace with the increased demand, however great that may become? Just as it is impossible to crack a stone boulder into pieces all of one desired size, it is impossible to carry on the cracking of petroleum except within certain prescribed limits. Moreover, a process which would crack up one kind of stone efficiently would fail entirely with another. Thus an oil-cracking process which might increase the yield of gasoline from eight to twenty-five per cent. on a mid-continental oil might not work at all on a Mexican or some other type of oil.

Why is it that some of the gasolines offered for sale to-day are degraded and will not start our engines in cold weather as well as used to be the case in earlier days? Simply for the reason that, as the demand grows more rapidly than the supply, the tendency is, following our analogy, to slightly increase the size of the holes in one of the screens so as to let more of the kerosene sizes mix in with the gasoline. If we want all fine screenings, we must so specify and pay the price, but gasoline is not manufactured to specification, and, so far as the public is concerned, it has nothing to say about the size of the holes in the screens.

In reality, of course, the distillation of oils has nothing to do with screens, but depends upon the temperatures at which the cuts on the different fractions are made. It is now clear, from what has been said, that when the chemist is through with the problem he turns it over to the engineer. If the engineer can design an engine that will start and operate as efficiently with a degraded gasoline, so much the better for all concerned. The producer will be helped out of many a trouble, and the consumer will get a cheaper fuel. But the chemist is not yet through with his end of the problem; he is beginning to find out that if he cannot simply crack up certain kinds of oils to make satisfactory motor fuel, he can first crack them up to the finest fragments and then put the fragments together again into new aggregated pieces or molecules which serve his purpose.

Since we have been dealing in analogies, let us suppose that a dairyman had been separating ten or twelve per cent. of cream

from his milk and making it into butter, getting whatever he could for the skimmed milk that was left. Then suppose that a chemist came forward and proposed to treat the skimmed milk in some manner so that another ten per cent. of cream could be separated, and the second crop of skimmed milk treated again to make a third lot of cream, after which two treatments the skimmed milk still remaining was at least as good for every purpose it could possibly be used for as it was at first. It is just this sort of thing the chemist is now at work on for the motor-fuel industry, viz.: to take the oil distillates, after all the gasoline has been removed, and treat them so that another crop of gasoline can be taken off, this treatment to be repeated as often as it pays to do so, the residue being still available as a fuel oil. At best such reprocessing could not go on indefinitely, for at each treatment of the oil distillates some free carbon or coke is split off from the molecules, and is a waste, so that such a method is by no means capable of getting something for nothing, although it has very practical possibilities. The daily press has from time to time got hold of a few details of the investgiations of some of the workers in this field, and has reverberated with exaggerations of the wonders that have been accomplished.

It is one thing, however, to work on a problem of this kind on the laboratory scale of operation, and quite another to adapt a new process to the big commercial scale of operation, as those of us who have had experience along these lines can most keenly realize. In working out such difficulties, the chemist and the engineer must join hands or, better, must exist in one and the same person, a member of that most modern of all professions, chemical engineering. Very often metallurgy must be called upon to develop new alloy steels especially made to exhibit great strength at comparatively high temperatures, while quite new types of machinery must be designed and tried out in service. Sometimes mistakes will be made and discouraging setbacks will occur, but, however great the obstacles and discouragements, the work goes on, for it is mainly by his mistakes that man learns to accomplish results in a few minutes or hours that Nature has taken her time over for untold ages. How long it takes Mother Earth to make a ruby or an emerald we do not know any more than we know how long it took her to make gasoline. Given the raw materials, we can make all these and many other things in a few hours, but

chemists working in these fields have labored patiently and lain awake very many discouraged nights before success was achieved, and then nine times out of ten, yes ninety-nine times out of a hundred, the credit is given to some well-advertised worker who merely began from some vantage-ground that somebody else had painfully climbed to.

Although not the result strictly of American chemical research, I would like to include in this paper some account of the wonderful work of chemistry in making synthetically from well-known raw materials useful substances that have heretofore been extracted from the sap of trees and plants indigenous to tropical or semi-tropical parts of the world. Among such substances we may particularly mention indigo, camphor, and rubber. Man-made indigo is already an article of commerce, while the manufacture of the other two has already been accomplished. Dr. Duisberg, a German scientist, was already able to say in 1912:

> "The end in view is this: that artificial rubber may soon play as important a rôle in the markets of the world as does natural rubber. The consumption of rubber is simply enormous. Finished articles to the value of three milliard marks are manufactured every year, and the raw material from which they are made, calculated at the present market price of 12 marks per kilo, costs one milliard marks. Other tasks which the chemist has on hand shrink into insignificance compared with this gigantic problem. The laurel wreath will not adorn the brow of the wild dreamer, but that of the scientist who, cool and persevering, pursues his way. The seed he sows ripens slowly, and though, according to the statements in the press, all this is mere child's play and the problem has been solved, I leave it to your judgment whether this is true or not, like much that printer's ink patiently transfers to paper. I am right in the midst of this excitement. I have employed articles made of synthetic rubber, and for some time I have used automobile tires made of this material. Yet, if you ask me to answer you honestly and truly when synthetic rubber will bring the millions which prophets see in its exploitation, I must reply that I do not know. Surely not

> in the immediate future, although synthetic rubber will certainly appear on the market in a very short time. But I hope to live long enough to see Art triumph also here over Nature."

The subject of chemistry and American industry covers too wide a field to be treated more than sketchily in a single paper. I have not space to refer to many interesting chemical developments in the field of metallurgy, of textile manufacture, of foodstuffs and medicinals, and last, but not least, of photography and the moving-picture film, destined to have so profound an influence on the education of the people. If what I have here written will stimulate the slightest interest in an appreciation of the usefulness and place of chemistry in our national development, my time will have been well spent.

I have endeavored to point out a few of a great many needs on the chemical side of industrial development in America. I have also ventured to point out what seems to me to be a national shortcoming, in the lack of interest and prevision exhibited both by our people and our government in regard to certain important factors of industry. Whatever has been stated is said in no spirit of carping criticism, but with the purely patriotic hope that a new leaf may be turned in the study of reasonable preparedness, whether in peace or war.

If we can have a Federal Reserve for money, why not a Federal Reserve for the necessities of our people that we do not adequately produce within our own boundaries?

A former president of the American Chemical Society, Mr. A. D. Little, once used words to this effect:

> "We have in this country the capital, the enterprise and the chemistry for great industrial achievements. That we cannot thus far point to them is due to the fact that with us chemistry is too often left like Cinderalla sitting beside the ashes of the laboratory furnace, while her two haughty sisters drive away to the industrial ball."

The Fairy Godmother in this case must be an awakened and intelligent public opinion which will be reflected in government, to the end that chemistry, capital, and enterprise shall be treated with equal appreciation and a fair and just generosity.

MULTIPLEXING IN CABLE TELEGRAPHY.*

BY

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THE use of alternating currents in cable telegraphy offers the great advantage that multiplexing is made possible. Among the many schemes which may be utilized, the method of using separate cables for sending and receiving, transmitting several messages on one cable and receiving a corresponding number on another, seems to offer the best solution of the problem where the volume of traffic warrants. In such an arrangement, we eliminate at once the artificial cable, which is an indispensable element in duplexing, and at the same time get rid of all the troubles incidental to the accurate balancing of the duplex bridge.

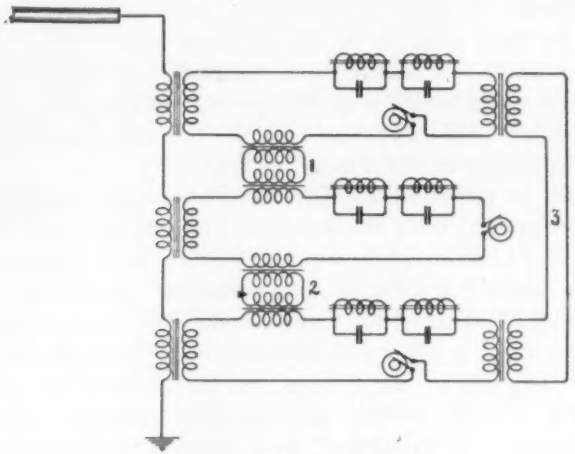
It must be remembered that the transmitted current is very large as compared with the received current, and any deviation from perfect balance in the ordinary method of duplexing may introduce disturbing effects on the receiver which would completely mask the effect of the received current. Even in using very low frequencies, say 5 cycles per second (150 cable letters per minute), the ratio of the transmitted to the received current in a long cable is about 20,000, and this ratio increases very rapidly as the frequency is increased. It is obvious that to balance out the large transmitting current to a sufficient degree so as not to affect the receiver is a difficult matter, and limits the speed of signalling, because the sensitiveness of the receiver is limited. But, even with all the refinements in balancing, the most that can be accomplished at present is the simultaneous sending and receiving of one message at each end of the cable.

In the plan proposed here of using two separate cables, one for sending and the other for receiving, the difficulties from balancing are completely done away with, and at the same time the working capacities of the cables can be greatly increased, a number of messages trasmitted on one cable, and a corresponding number received on another cable.

* Communicated by the Author.

The method proposed is shown schematically in the two accompanying figures. In Fig. 1 an arrangement is shown for transmitting three messages simultaneously on one cable. We have here three local transmitting circuits coupled to the cable, the frequency of each transmitter being different from any one of the others, say 6, 8, and 10 cycles. In each local transmitting circuit two loop circuits are included which are separately tuned to the frequencies of the other two transmitters, offering thereby a high impedance to the current flow of these frequencies, thus preventing the transfer of current from one transmitting circuit to the

FIG. 1.



Transmitting terminal.

others. To further check any transfer of current fom one local circuit to another, the intermediate circuits 1, 2, and 3 are introduced through which e. m. f.'s of opposite phase to that induced by way of cable transformers are induced, and thus balancing out and residual effect from one circuit on another.

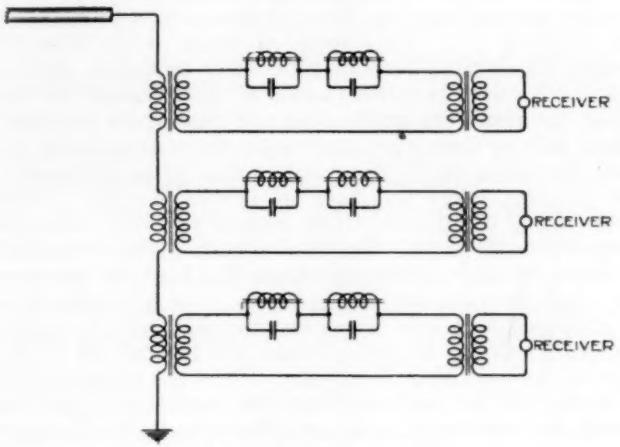
In Fig. 2 a receiving terminal of a cable is shown in which three circuits are used for the reception of three messages simultaneously. Each receiving circuit is coupled to the cable through an intermediate circuit. In each intermediate circuit two loop circuits are included which are separately tuned to the frequencies of the signals which are to be excluded from that particular receiver, each receiver responding accordingly only to a signal of

one predetermined frequency and excluding the others. If desired, loop circuits may also be introduced in the receiver circuits, and thus further increase the selectivity.

In the arrangement described above, the disturbing effects of local transmitter on receiver, which are always present to a greater or less degree in duplexing, are entirely eliminated, and as a consequence detectors and amplifiers of very much greater sensitiveness may be employed.

For purposes of illustration three transmitters and three receivers are shown, so that two cables could handle three messages

FIG. 2.



Receiving terminal.

both ways, but obviously the method outlined above is not limited to this number. It would be necessary, of course, to increase somewhat the complexity of the circuit arrangements, increasing the number of loop circuits and intermediate circuits employed in the transmitting and receiving circuits, but this would not offer any serious difficulties. The experience with radio telegraphy offers a similar case, although, of course, the ratio of the transmitting current in the sending antennæ to the receiving current in the receiving antennæ is very much greater than 20,000, as is the case in an ocean cable. The practical solution at present used in radio telegraphy is to employ two separate antennæ, one for transmitting and one for receiving, the pair furnishing the complete

telegraph terminal. The plan outlined above for the case of ocean cables is similar in principle and is proposed for similar reasons.

The present war has emphasized the supreme importance of ocean cables as never before in the history of the world, and as a result it is believed that as soon as peace is established it will be well worth while to carefully consider a comprehensive plan of cable laying based on the maximum of international service.

WASHINGTON, D. C., April 17, 1917.

A Plate Fulcrum Track Scale. J. H. A. BOUSFIELD. (*Railway Age Gazette*, vol. 62, No. 10, p. 395, March 9, 1917.)—The Pennsylvania Railroad, one of the pioneers in the use of plate fulcrum track scales, recently installed the first two-section track scale of this type at Pitcairn, Pa. This form of construction eliminates the knife-edges which have been of practically universal application in scales of all kinds. In consequence of this change, the need for regrinding and renewing knife-edges and bearings is avoided. Similarly, dead rails or their equivalent in the form of relieving gears are avoided. As indicated by the name, a thin plate, continuous from lever to bearing, takes the place of the knife-edge. These plate fulcrums consist of relatively thin central portions connecting two heavier portions or heads. The thin portion gives the desired flexibility, while the large heads distribute the load on the supporting members and decrease the unit stresses. The thin central portions are all arranged to act in direct compression, but are subjected to a slight flexure as the weighing beams vibrate and the lever system responds to the condition of balance. Thus the necessary vibration is taken care of without entailing the inevitable wear that takes place with the knife-edge scale, and the thin plates of steel remain in their original condition, regardless of the amount of weighing that is done by the scale.

The effective length of the weighing rail is 52 feet. The scale is of the two-section type, wherein four main transverse levers—two at each end of the track-supporting girder—transmit the load to two longitudinal extension levers, which in turn transmit to a transverse extension lever connected directly to the weighing beam. Only seven levers are used in the scale, thus effecting greater simplicity in construction than in the four-section type of scale with equal efficiency. The main girders are so designed that a test car can be placed directly over the centre line of a section, thus providing an effective means for accurate calibration. The main weighing beam is graduated to 300,000 pounds by 1000-pound notches and a fractional bar to 1000 pounds by 50-pound notches. An auxiliary weight is provided to raise the capacity to 400,000 pounds. The plate fulcrum principle is that used for many years in the highly refined Emery testing machines.

FERROMANGANESE IN THE IRON AND STEEL INDUSTRY.*

BY
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1. INTRODUCTION.

At the present time, and for the past two years, the situation in this country relative to a dependable supply of manganese ores, and also ferromanganese alloys for use in iron and steel metallurgy, has been extremely serious. The situation will remain so as long as the European war continues, and will no doubt become acute in the event of this country becoming involved in the conflict. Before the war ferromanganese was not produced in this country except by one company in any amount, and practically no manganese ores were mined. Manganese mining has never assumed the proportions of an industry in the United States because of the small extent and scattered nature of most of the deposits. Further, most steel makers felt no urgent necessity for producing ferromanganese, nor were independent makers disposed to enter the field, for the reason that an abundant supply of the alloys had always been obtainable from foreign sources, and usually at exceedingly reasonable prices, say $45 per ton, seaboard.

The manganese ore used in this country in the manufacture of ferromanganese has been hitherto mainly secured from three principal sources; viz., Russia (southern), India (southern British), and Brazil (east central). For a large number of years these three countries have outranked all other producing countries in the output of manganese ores. For the five years preceding the European war, Russia produced annually about 844,000 long tons, India 694,000 long tons, and Brazil 200,000 long tons.[1] Both the Russian and Indian outputs have suffered a falling off since the war started, but the Brazilian output has increased by leaps and bounds until its 1916 production is rated at about 650,000 tons, as near as can be estimated from figures available. Prior to the war a large amount of our imported manganese ore came

* Communicated by the Author.

[1] Singewald, Joseph T. Jr., and Miller, Benj. L., "The Manganese Ores of the Lafayette District, Minas Geraes, Brazil," in *Bull. A.I.M.E.*, October, 1916, p. 1745 *et seq.*

from India and *via* Germany and England. At the present writing Brazil is the principal foreign source.

Since the war started, the receipt of both ores and alloys from the belligerent nations and their colonies has been decidedly uncertain, and this, together with the embargoes laid by England at different times, made necessary the taking of the Brazilian output in large amount. The manganese ores of India have been shipped mainly to England, while the shipment of those from the Russian Caucasus practically ceased when Turkey entered the war with the concomitant closing of that valuable exit, the Dardanelles. Hence it is clear that, of the three important producing countries, but one has been able to furnish ores continuously, and this has been done by Brazil. As will be further mentioned later on, it would seem as though the time were opportune for reopening the abandoned Chilean deposits, which are now much more available through the opening of the Panama Canal and also through the exploitation of iron ores there at present. The shipment of Chilean manganese ores should go a long way toward making up the deficit caused by the curtailment of shipments from India and the complete blocking off of the Russian ores.

The ferromanganese alloys have not been received in any quantity since the war started, and of necessity a new domestic industry has arisen in this country; viz., the production of ferromanganese for the market. Prior to the war, England furnished most of the ferromanganese used here (*i.e.*, the high percentage (80 per cent.) alloy), and Germany shipped a subordinate tonnage. As already pointed out, English embargoes at different times since the war started cut off imports, and no shipments have been received from Germany. Germany, of course, has no ferromanganese to sell even if it were possible to get it out of the country, being practically at starvation ebb for steel-making supplies, and particularly manganese, if reports are true. The decrease in imports, together with the terrific pace of steel production in the past two years, quite naturally caused a heavy demand for ferromanganese, and, consequently, heavy increase in prices. Prices were high indeed, and manipulations of the market by speculative traders carried the quotations to unheard-of levels.

2. SOURCES OF MANGANESE ORES.

The main sources of manganese ores, as already mentioned, are the producing mines of Russia, India, and Brazil. The geo-

logical occurrences of the ores have been described at some length in the scientific press by Harder,[2] Drake,[3] and others, and any further account in this article appears to be superfluous. Very briefly, the ores of Russia have come in the main from the Tchiatouri deposits in the central part of the Caucasus, and some ore has been produced in the Nikopol district. The mode of mining was, until about ten years ago, exceedingly primitive, being conducted by peasants, but of late years foreign capital has become interested, and modern methods of extraction have been installed.

The manganese ores of India have been described mainly by Fermor,[4] and also Harder.[5] The ores occur at a large number of localities, but the only deposits of known economic importance are those of the Jhabua district of Central India; the Panch Maháls district of Bombay; the Chhindwára, Bálághát, Bhandára, and Nágpur districts of the Central Provinces; the Sandur and Vizagapatam districts of Madras; the Shimoga district in Mysore; and the Gangpur district in Bengal.[6] There are a number of operating mines producing high-grade ores in which the manganese shows 50 per cent. and more on analysis. Ore blocked out and in reserve indicates that these mines will be in a position to be constant producers for many years to come.

Manganese ore is known in Brazil in the states of Bahia, Minas Geraes, and Matto Grosso. The mining of the ores dates back to 1894, the main bulk of the output having come from Minas Geraes. The districts have been described by Singewald and Miller,[7] Harder,[8] Scott,[9] Derby,[10] *et al.* In late years the

[2] Harder, E. C., "Manganese Ores of Russia, India, Brazil, and Chile," *Bull. A.I.M.E.*, May, 1916, p. 761 *et seq.*

[3] Drake, Frank, "The Manganese Ore Industry of the Caucasus," *Trans. A.I.M.E.*, xxviii, pp. 191–208, 1898.

[4] Fermor, L. L., "The Manganese Ore Deposits of India," "Memoirs Geological Survey of India," vol. xxxvii, pts. 1–4.

[5] Harder, E. C., *loc. cit.*

[6] Harder, E. C., *loc. cit.*

[7] Singewald, Joseph T. Jr., and Miller, Benj. L., *loc. cit.*

[8] Harder, E. C., *loc. cit.*

[9] Scott, H. K., "The Manganese Ores of Brazil," *Jour. Iron and Steel Inst.*, No. 1, 1900, p. 189.

[10] Derby, O. A., "On the Original Type of Manganese Ore Deposits of the Queluz District, Brazil," *Am. Jour. Sci.*, 4th ser., vol. xxv, pp.213–216, 1908, and "On the Manganese Ore Deposits of the Queluz (Lafayette) District, Minas Geraes, Brazil," *Ibid.*, 4th ser., vol. xii, 1901, pp. 19–23.

Queluz or Lafayette district of Minas Geraes has outstripped the Miguel Burnier district nearby with the development of the phenomenal Morro da Mina mine, so that the Lafayette district has assumed foremost importance in Brazil. Development work has disclosed an ore reserve of about 10,000,000 tons, and the mine is producing at the rate of over 200,000 tons per annum.

As previously alluded to, manganese ores have been mined in Chile; the industry was carried on quite extensively prior to 1900, or about the time when the extensive Indian deposits began to be exploited. Since 1905, practically no manganese ore has been mined in Chile, and the mines have been abandoned. Manganese ores occur in the Huasco and Carrizal districts of Atacama; the Los Chorros, Los Cañas, La Liga, Arrayan, and Corral Quemada districts of Coquimbo, and the Aculeo district of Santiago. Most of the exported Chilean ore came from the Carrizal and Corral Quemada districts, and a considerable tonnage from Los Cañas and La Liga.

Manganese mining has never been an important industry in the United States on account of the scattered and discontinuous nature of the deposits.[11] Deposits are found in many localities, but in only a few places do they occur in sufficient quantity to be of high commercial value. Ores have been mined in the New England, Appalachian, and Piedmont regions in the eastern United States, in northern Arkansas, and to a small extent in California in the central western part. The main mines as to production have been those in the Blue Ridge and the James River-Staunton River region of Virginia, the Cartersville and Cave Spring districts of Georgia, the Batesville district of Arkansas, and the Livermore Telsa district of California.

3. PRODUCTION OF FERRO-ALLOYS; AND THE TRADE SITUATION.

In 1914 there was only one company that made ferromanganese this side of the Atlantic, and none of this production was sold in the open market; it was all used for private needs. Most of the spiegeleisen prior to 1914 was made in Pennsylvania from a manganiferous residuum that is a by-product from a zinc smelter. About 90,000 tons of the total of 106,980 tons made in 1913 were made at that point; the remainder was turned out by a Colorado plant and by an Illinois steel plant for their exclusive

[11] Harder, E. C., "Manganese Deposits of the United States," *Bull. 427, U. S. Geological Survey*, 1910.

use in the manufacture of Bessemer steel. In 1913 the United States was the only country which did not make its own total consumption of ferromanganese, which, in the light of the importance of its steel industry and the fact that the other countries making their own ferromanganese draw their ore from outside sources, appears to be a rather singular thing.

The history of the manufacture of ferromanganese in the United States dates from the outbreak of the European war, summer of 1914. It appears that in no other substance entering intimately into the manufacture of steel have the war and the conditions brought about thereby produced such a radical effect upon domestic production and demand as in ferromanganese. The war itself, and coincident industrial activities, showed clearly the dependence of American steel makers upon European sources to furnish an adequate supply of one of the most essential ingredients in steel-making processes. Nor was there any vital reason for this, other than the excuse that foreign ferromanganese was cheap and abundant and prior to 1914 there was no indication that the supply would ever be cut off. As in the dye industry, this indicates the alarming improvidence of American manufacturers. England and, in a lesser degree, Germany, who have furnished the greater part of the ferromanganese used in this country, have made the alloy from imported ores, coming from Russia, India, and Brazil. It appears, in the light of the developments of the past two years, that the manufacture of ferromanganese on a commercial scale has come to be an important domestic industry, but it will remain so only so long as we have an abundant supply of ores. The closer trade relations which have been secured with South American countries seem to indicate that the greater portion of our manganese ore will come from Brazil in the future.

No one probably has ever doubted the ability of American metallurgists to produce both ferromanganese and spiegeleisen of as good a quality as the foreign products. Prior to 1915, practically the only producer of ferromanganese in this country was the United States Steel Corporation. This corporation required such large tonnages of both ferromanganese and the lower quality alloy that it could not run the risk of depending on imported products and market speculations, so that it met its own requirements, and almost entirely from imported ore.

During 1915 three independent steel companies commenced making ferromanganese; these concerns were the Colorado Fuel and Iron Company, the Jones & Laughlin Steel Company, and the Maryland Steel Company. Several other concerns also made ferromanganese and spiegeleisen for the market, as follows: The American Manganese Manufacturing Company, which controls the Dunbar, Pa., blast furnace; the Noble Steel Company, of San Francisco, and the Electro-Metallurgical Company, of Niagara Falls: the last two operate electro-metallurgical processes for production. The American Manganese Manufacturing Company has made elaborate plans for the production of merchant ferromanganese at Dunbar, and both the high alloy and spiegeleisen have been made. The story of the production of both ferromanganese and spiegeleisen in this country in 1916 is unequalled in the annals of the steel trade. Had not the demand for both had been met at home, the record year in steel production would never have been chronicled. The past year was no doubt the most remarkable both as to production and consumption. The imports of ferromanganese from England, which had been 28 per cent. of the total consumption in 1915 and from 45 to 60 per cent. for several years before the war, fell off to 25 per cent. in 1916. The production of spiegeleisen was the largest since 1907, when the Bessemer process was at its height (see Table I), amounting to 170,000 tons, as compared with 114,556 tons in 1915.

TABLE I.*

Imports and Domestic Production of Manganese Alloys: Imports of Ore.

	Production		Imports		Imports
	Ferro-manganese	Spiegeleisen	Ferro-manganese	Spiegeleisen	Manganese ore
1916	270,000†	170,000†	95,000†	.....	575,000†
1915	144,260	114,556	55,263	200	313,985
1914	100,731	76,625	82,997	2,870	283,294
1913	119,495	106,980	128,070	77	345,090
1912	125,378	102,561	99,137	1,015	300,661
1911	74,602	104,013	80,263	20,970	176,852
1910	71,376	153,055	114,228	25,383	242,348
1909	82,209	142,831	88,934	16,921	212,765
1908	40,642	111,376	44,624	4,579	178,203
1907	55,918	283,430	87,400	48,994	209,021
1906	55,520	244,980	84,359	103,268	221,260
1905	62,186	227,797	52,841	55,457	257,033

* *The Iron Trade Review*, January 4, 1917, p. 24. †Estimated.

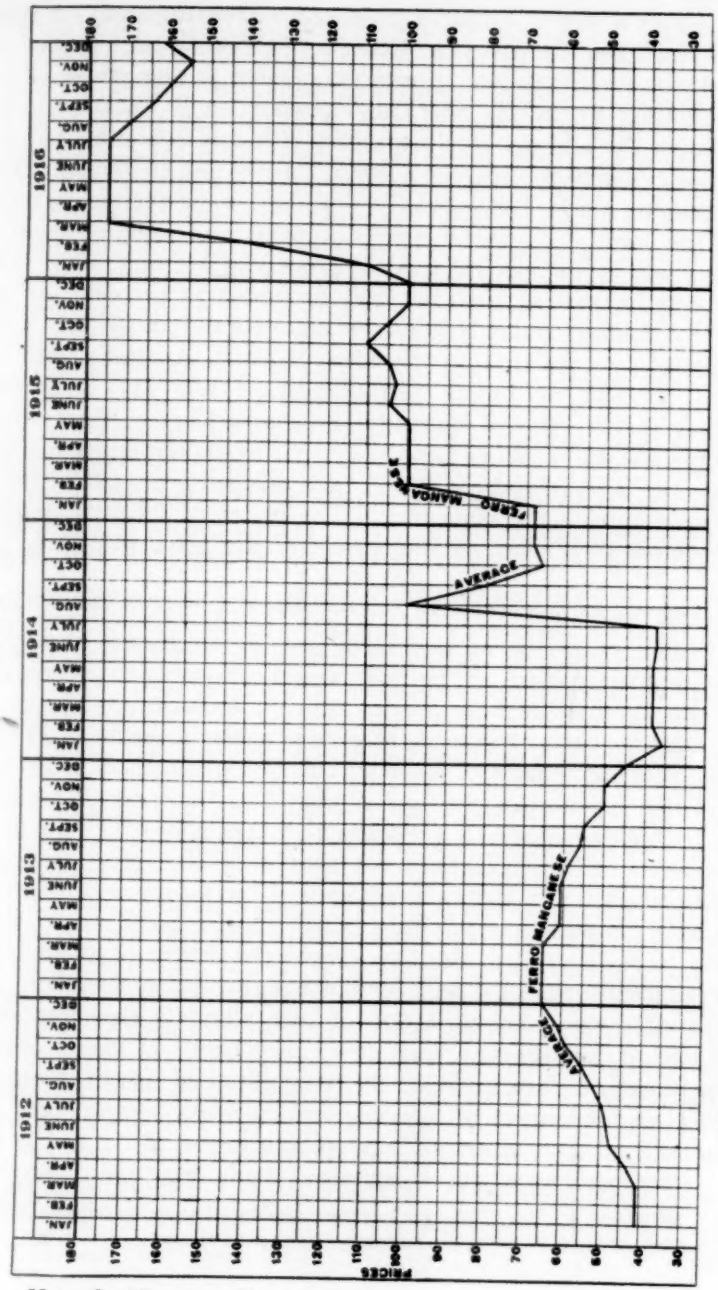


FIG. 1.

Contract prices for ferromanganese, tidewater, 1912–1916. (From the *Iron Trade Review*, January 4, 1917, p. 25.)

About a dozen furnaces produced ferromanganese or spiegeleisen during the past year, either for sale in the open market or for private consumption. Furnaces operated on manganese alloys at Dunbar, Cornwall, Sheridan, Newport, and Lebanon, Pa.; Chicago, Ill.; and also steel work blast furnaces at South Chicago, Ensley, Pittsburgh, Sparrows Point, Pueblo, and elsewhere. The Kittanning stack, Pennsylvania, produced some ferromanganese for the Jones & Laughlin Steel Company, and some production was made by the electric furnace process at Heroult, Cal. The domestic makers in 1916 not only produced 75 per cent. of the home consumption, but both ferromanganese and spiegeleisen were exported to Canada, Italy, Sweden, Holland, Australia, etc. A small amount of Indian ferromanganese was also imported. Prices in 1916 reached figures hitherto unparalleled. Spot ferromanganese sold at above $450, seaboard, the highest figure reached since the Russo-Japanese War. Spot spiegeleisen touched $100, furnace, during the same time. The prices of ferromanganese, as compiled by *The Iron Trade Review*, are given in Fig. 1.

4. THE USE OF MANGANESE IN THE METALLURGY OF IRON AND STEEL.

In every process of steel metallurgy it is common to employ one, and often more, of the ferro-alloys, according to the kind of steel being made and the use for which it is destined. By reason of total tonnage consumed, ferromanganese is the most important of the ferro-alloys. Its importance may be realized when it is said that its use is virtually indispensable. In a recent paper,[12] F. H. Willcox, of the U. S. Bureau of Mines, pointed out the great importance of manganese in the metallurgy of steel. The scientific press has not generally recognized the significance of manganese; the trade journals have called attention to our dependence upon foreign sources and have urged the matter of research to develop substitutes for both ferromanganese and spiegeleisen. In view of the well-known action of both alloys in the metallurgy of steel, it is needless to recall their effects here. However, it may not be out of place to sketch the possibilities of substitute deoxidizers and the means of securing data thereon. In any event, the scientific method of attack is the practical one.

Ferromanganese and spiegeleisen, aside from their recarbur-

[12] Willcox, F. H., "The Significance of Manganese in American Steel Metallurgy," Bull. A. I. M. E., February, 1917, p. 99 *et seq.*

ization effects, are added to steel for the purpose of deoxidizing the metal and for the purpose of removing gases and oxides therefrom. In general, the following substances mainly have been used as deoxidizers and purifiers: ferromanganese and spiegeleisen; aluminum, ferrosilicon, and ferrotitanium, either carbon-free or not. To a much less extent, the following substances have found application for the same purpose: ferro-aluminum; ferromanganese-silicon, or, as it is more commonly called, silico-manganese; ferro-silico-manganese-aluminum; ferro-silico-aluminum; silico-calcium-aluminum; ferro-vanadium; calcium-silicide; ferro-calcium-silicide; ferro-titanium-aluminum-silicide, and some others.

Ferromanganese.—As already pointed out, manganese, in the form of one of its iron alloys, is the most important deoxidizer known. As commonly recognized, ferromanganese is an alloy of about 80 per cent. Mn, 15 per cent. Fe, and 5 per cent. C. Strictly speaking, it is rather more of a manganese alloy than one of iron, although it is classed with the ferro-alloys. Spiegeleisen is a low-grade iron-manganese alloy of about 10 to 25 per cent. Mn, and occasionally up to 35 per cent. Mn, and about 5 per cent. C. The higher-percentage alloy hastens the chemical reactions in the steel more rapidly than does the lower-percentage alloy, and accordingly absorbs less heat in so doing. Certain advantages are found in using the higher alloy; among other things, a smaller quantity of the former will be required to produce the same results, and consequently the loss through volatilization and for other reasons, when added in the solid state, will be minimized. This point will be dealt with at greater length in a later paragraph, as it is an important one.

Ferromanganese is used in cases where it is undesirable to materially increase the carbon content of the metal, as happens when spiegeleisen is added. The former is therefore of great importance in the manufacture of manganese steels. Typical 80 per cent. English ferromanganese may analyze as follows: 80.00 per cent. Mn, 7.20 per cent. C, 0.80 per cent. Si, 0.18 per cent. P, 0.004 per cent. S, and 11.20 per cent. Fe.[13] Spiegeleisen has found and still does find extensive application in the manufacture of Bessemer steel, although at present ferromanganese is used in conjunction with it in this practice. A typical English spiegeleisen analyzes 20.11 per cent. Mn, 4.99 per cent. C, 0.42 per cent.

[13] Carnegie, D., "Liquid Steel."

Si, 0.074 per cent. P, and S nil.[14] Irrespective of which alloy is added, and whether in the steel-making appliance or in the ladle or both, certain chemical reactions occur. The manganese, by reason of its greater chemical affinity for oxygen, robs the iron or steel bath of the dissolved iron oxides with the formation of manganese oxide (MnO), which is insoluble in the metal. The MnO joins the slag, and the reduced iron is given up to the bath according to

$$Mn + FeO = MnO + Fe.$$

The deoxidizing effect of manganese is very potent, but it will not remove the last traces of oxides from the metal, nor will it remove dissolved gases; *e.g.*, nitrogen. The last traces of oxides may be scavenged out by the use of aluminum or titanium alloys, after the addition of the manganese. In addition to its action upon oxides, manganese is valuable because of its chemical reaction with sulphur. In a frozen steel, sulphur, unless sufficient manganese be present, is in the form of ferrous sulphide (FeS), which is thrown out to the crystal boundaries in such a manner as to give rise to extreme weakness and brittleness of the metal when hot. Manganese has a greater chemical affinity for sulphur than has iron, so that, when added to steel, manganese sulphide (MnS) is formed in whole or in part, dependent upon the percentage of manganese added, according to

$$Mn + FeS = MnS + Fe.$$

Some of the MnS may go to the slag, and some of it remains in the metal as rounded inclusions.

Aluminum.—This metal will remove traces of oxygen from steel when added in small amounts. Aluminum is a more efficient deoxidizer than either manganese or silicon, but its use is not entirely without certain disadvantages. The element, when added to molten steel, reduces ferrous oxide according to

$$2\ Al + 3\ FeO = 3\ Fe + Al_2O_3.$$

As the equation shows, the reaction produces the very highly infusible Al_2O_3. As the temperature of the bath is usually below

[14] Carnegie, D., *loc. cit.*

the melting-point of this oxide, the tendency then is for the aluminum oxide to remain occluded in the frozen metal instead of entering the slag as desired. The use of too much aluminum tends toward the production of large pipe, and for this reason some railroad engineers specify that it must not be used as a deoxidizer for rail steel. Further, it has no effect upon sulphur. The benefits gained from the use of aluminum arise from the exothermic reaction induced on combining with oxygen, and since, on its addition, the metal is killed and thereby quieted, segregation is decreased. However, it cannot be used as a substitute for manganese because of its limitations.

Ferrosilicon.—This alloy, formerly made in the blast furnace as a highly silicated pig iron containing from 10 to 12 per cent. Si, is now made in the electric furnace and may contain up to 95 per cent. Si. Typical English ferrosilicon made in the blast furnace analyzes 13.45 per cent. Si, 1.21 per cent. C, 1.71 per cent. Mn, 0.058 per cent. P, and 0.02 per cent. S. Ferrosilicon made in the electric furnace may contain 25 to 35, 45 to 50, 75 to 80, or 90 to 95 per cent. Si. A typical English electric-furnace ferrosilicon analyzes 94.8 per cent. Si, 0.08 per cent. Mn, 0.01 per cent. P, 0.02 per cent. S, and C *nil*. The 25 to 30 per cent. ferrosilicon may be used to advantage in large pieces in both the open-hearth and Bessemer processes. Ferrosilicon is, as a rule, added to steel in the furnace, but occasionally in the ladle before the steel is tapped. Ferrosilicon is very effective in steel metallurgy because of the high chemical affinity of silicon for oxygen. Added in small percentages, as low as 0.1 per cent. by weight, it is said that it reduces segregation and increases the solvent power of the steel for gases. When added in excessive amount it produces pipe. Ferrosilicon owes its value to its ability to remove the oxygen by forming readily fusible silicates with Ca and Fe, but in some cases SiO_2 remains in the steel because of its infusibility. In any event, ferrosilicon cannot be regarded as a substitute for ferromanganese.

Ferrotitanium Alloys.—Both ferrocarbon titanium and carbon-free ferrotitanium have found quite extensive application in steel works metallurgy in late years for the purpose of deoxidizing and denitrogenizing metal, but their warmest adherents or the companies manufacturing them do not suggest that they be used as

substitute deoxidizers for ferromanganese.* They are regarded as so-called super-purifiers, and leading authorities seem agreed as to their beneficial effects. That the alloys have found favor in practice is recognized, because a large industry has been reared upon the production and sale of ferrocarbon titanium, and in another works ferrotitanium is one of the principal products. It appears difficult to incorporate titanium in steel as an alloying element, but the metal combines with nitrogen with very great avidity and is practically the only one which removes dissolved nitrogen in present-day work.

Other Deoxidizers.—Some of the other deoxidizers already mentioned have found a limited use; where they contain three or more elements in the alloy, these elements apparently augment one another's effects, but whether some of them are suitable or not is difficult to say. Whether they are or not, they have not enjoyed much use in modern practice.

5. THE USE OF LIQUID FERROMANGANESE.

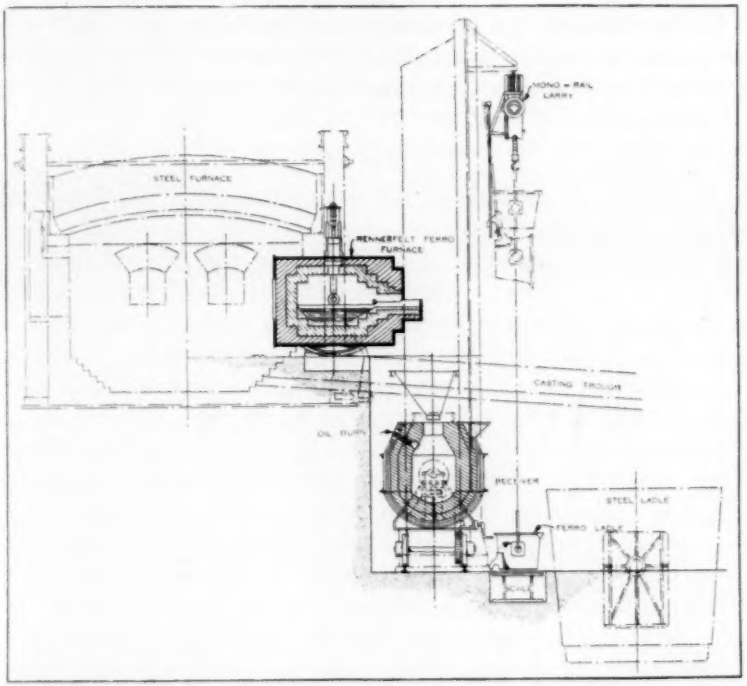
In view of the utter dependability of steel makers upon foreign sources for their manganese supplies, it is little short of surprising that more time has not been spent upon the subject of substitute deoxidizers or even on the matter of conserving the available manganese supply. When spiegeleisen, the low-percentage manganese alloy, is melted in cupolas, the large clouds of red smoke constantly issuing from the cupola tops indicate the utter extravagance of such a method. For melting the high-percentage alloy, the cupola is totally out of consideration. Various furnaces, fired by coke, coal, gas, or oil, have been tried for melting manganese alloys for liquid addition without satisfactory results. The standard method of adding ferromanganese (*i.e.*, the high-percentage alloy) has been to break the alloy up into lumps and shovel it in in the solid state; in many European works the alloy is preheated red hot before adding. However, the experience of practice has shown the extravagance of this method also, because the loss in manganese totals from 20 to 35 per cent. from vola-

* NOTE.—In this connection, the work of W. A. Janssen, described in "The Use of Titanium in the Manufacture of Steel Castings," Cleveland meeting, 1916, American Foundrymen's Association, is interesting, as it represents the first recorded attempt to substitute ferrotitanium for ferromanganese in part.

tilization. If this could be recovered it would represent a yearly saving, in a plant making 300,000 tons of steel per annum, of about $26,000, figuring ferromanganese at $55 a ton. At the price paid for ferromanganese in the past two years, the saving would be a great deal more. Naturally, whether it would pay to make this saving would depend upon the cost of so doing.

Among others, Alex. Sahlin, of Brussels, has prominently

FIG. 2.



Rennerfelt melting furnace and scheme for large plant making heavy heats. (After Sahlin.)

pointed out how melting ferromanganese in the electric furnace is both practical and economical.[15] No practical method for melting was available until the advent of the electric furnace, but now a number of plants in Europe have installed ferromanganese melting furnaces. Heroult, Girod, Nathusius, and Keller arc furnaces, as well as the Roechling-Rodenhauser induction furnace,

[15] Sahlin, Alex., "The Use of Liquid Ferromanganese in the Steel Processes," *Jour. Iron and Steel Inst.*, 1914, No. 2, p. 213 *et seq.*

are used. The cost of electric current for operating constitutes the principal expense item. Irrespective of the working of the method, it is stated on good authority that worth-while savings can be effected, and those interested can refer to the account by Sahlin. The Rennerfelt furnace, brought out in 1913 by Ivar Rennerfelt, has proved particularly applicable for ferromanganese melting. Using this furnace, the layout in Fig. 2 is recommended for large steel works making heavy heats. Where high-grade or special steel is being made, and cost is a minor consideration, as in the manufacture of manganese steel castings,[16] the ferromanganese is melted in crucibles or in small, specially-designed reverberatory furnaces. This method of procedure would not do for general work.

6. RÉSUMÉ.

It appears, in the light of the facts presented in the foregoing, that the manganese situation is one of serious importance—one that warrants thoughtful consideration on the part of those interested in the subject. The possibility of metallurgical science discovering a substitute deoxidizer which will take the place of manganese, either in whole or in part, appears to be an alluring one. Naturally, any attempt at such an endeavor will call for a large amount of labor on the part of many men, and it is not to be supposed that the final solution of the problem will be effected in any short time. The matter of obtaining suitable coöperation with steel makers for the use of their plants so that experiments may be carried out on a scale commensurate with that of practice is one that will have to be taken care of by research men who hope to contribute in large measure to any progress along this line. Steel works laboratories have an opportunity before them, if they have not already grasped it—and they apparently have not, if published data can be any criterion. A recent investigation [17] carried out in this country appears to be the first well-defined attempt in this direction.

CLEVELAND, OHIO, February 21, 1917.

[16] McKee, W. S., "Making Manganese Steel Castings," *Iron Trade Review*, February 15, 1917, p. 413 *et seq.*, from a paper at the Cleveland 1916 meeting of the American Foundrymen's Association.

[17] Boylston, H. M., "Investigation of the Relative Merits of Various Agents for the Deoxidation of Steel," Carnegie Scholarship Memoirs of the Iron and Steel Institute, vol. 7, 1916, p. 102.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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HISTOGENESIS AND PHYSIOLOGY OF THE LIGHT-TISSUES IN LAMPYRIDS.

As was said in the previous chapter, the fire-fly begins life by being all luminous, by showing a pale luminosity from all of the peripheral cytoplasm of its one-celled oösperm or egg. We do not know whether this power extends back into sperm or ovum or not. That sex has an influence on this secretion of luciferine granules is evidenced by the fact that the minute granules are round in the male and rod-shaped in the female when the adult organ is developed. During the resulting cleavage and differentiation of the fertilized ovum this power of secreting photogenin still persists.

Some writers have assumed that the pale light of the egg came from the yolk bodies, but it is a far better plan to assume that it is developed from granules of luciferine secreted from, and contained in, the cytoplasm of the ovum. Whether it would, under those circumstances, show as a brighter light in such parts of the cytoplasm as are most concentrated or not is a question that has not been studied by experiment or observation. On the other hand, it seems probable that it is confined to the ectosarc, which must be regarded as the most highly differentiated part of the organism even at this early period.

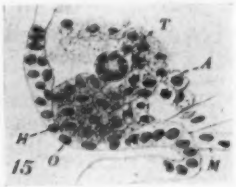
During the later cleavage and differentiation of the oösperm the light power appears to become segregated in a small group of cells that form the anlage of the future light-organ. The exact method of this segregation has not been studied closely, but R. Vogel has seen it in embryos of 18 days' incubation. He shows that it has some relation to the fat bodies and that it does not originate from an imaginal plate.

F. X. Williams has made what are probably the most complete studies on this question, although they leave much further study to be desired. He does not give us the age of the embryonic larva in which he was able to identify the developing light-organ, but

* Continued from page 348, vol. 183, March, 1917.

it was quite young, as can be seen from Fig. 1, which is copied from Williams's paper. In this stage (Fig. 1) the light-organ appears as a mass of polyhedral cells lying in each side of the eighth segment between its anterior end and its tracheal stigmata. The upper portion of the mass rests against cells that are forming the fat-body, and it is a fair question if these light-cells were derived from the fat-body or from the mesodermal cells that the fat-body also came from. The probability that it has been derived from fat tissue is much enhanced by the fact that its cells appear to form a series of stages that grade into the fat-cell type at the point of contact; also, the indeterminate cells on the border between fat-body and light-organ are multiplying by mitosis. On the ventral and lateral edge of this rudimentary organ it rests against the integument, which at this stage is composed of only

FIG. 1.



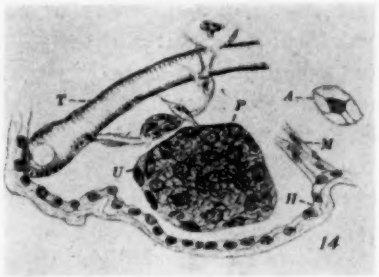
Section of developing light-organ in a young embryo of *Photuris pennsylvanica*. *O*, light-organ; *A*, fat-body; *H*, hypodermal epithelium; *T*, young tracheal tube. (After F. X. Williams.)

the hypodermal layer of cells, no cuticle having as yet appeared. Here it rests in close contact with this epithelium and still is marked off from it by a distinct boundary. It appears almost as probable, but yet not quite so, that the light-cell mass was derived from this layer of epithelial cells as from the fat-cells.

A tracheal branch is already coming to this embryonic organ and appears at *T*, although its invaginated cells have not yet secreted any cuticle, and therefore no lumen is as yet present. This immature organ is already giving forth light, and this raises some interesting questions. Has the light-producing power been entirely segregated in these cells, and, if so, was it an inheritance through the cytoplasm or the chromatin of the weakly luminous oösperm? In the first place, the embryonic anlage of the light-organ shows at all stages the power of lighting, and it probably carried this power with its constituent cells from the first cleavage.

But several other things have to be accounted for. They are, first, that a new light-organ will later be developed in the adult from cells that do not form a part of this larval organ, but from either fat-cells or hypodermis. Secondly, the germ-cells, either spermatozoa or ova or both, must carry the power to be developed in the next generation. Thirdly, Williams has observed that while in the pupal stage the thorax shows a diffused and moderately weak but definite glow, so that some cells in this region must also develop the photogenic power, even if only temporarily. These three kinds of cells, then, in the young fire-flies' bodies, outside of the regular light-organ, must all have the potential power of secreting luciferine at certain times in their history. It

FIG. 2.



Section of developing light-organ in a somewhat older embryo of *Photuris pennsylvanica*. The organ has separated from hypodermis (*H*) and fat-body (not shown) and is now supplied with nerve and tracheal branches. The reflector layer (*U*) is beginning to differentiate from the luminous portion (*P*). (After F. X. Williams.)

would therefore seem that they have an inherited tendency that only comes into operation at certain times in several varieties of tissues.

We are reminded at this point of Peter's work on the Ctenophores. He found that the oösperms were not capable of lighting, but that after a very few cleavage divisions the embryos had acquired the power of emitting a flash of light. Later this power is confined to certain cells near the paddle plates, but Peters never found through which cleavage cells the power was transmitted.

The next step in the development of the larval organ that Williams saw is represented by his figure that has been copied as Fig. 2 of this work. The age of the embryo is not stated, but it

had chitin and hairs well developed and was moving freely about within its egg. The organs were visible from without as two well-defined points of light shining through the shell. The development is far advanced in this stage from that seen in Fig. 1. The rounded mass of cells is clearly removed from any contact with the fat-body or with the hypodermis. Its cells show a very slight beginning of the differentiation into luminous and reflector layers. The strands of tracheal epithelium which appeared as thick heavy tubes with no definite lumen in the previous stage, where they had scarcely reached to the light-organ, are here formed of thin, distinctly flattened epithelial cells that have secreted the tracheal tubes of chitin, and these tubes now penetrate the light-organ and branch, to furnish it with its supply of air.

Where the light-organ measured only 17 × 21 micra in the previous stage, it now reaches a diameter of 24 × 34 micra. In its full grown larval form it measures 451 × 577 micra.

The above short sketch of the early development of the larval light-organ is practically all that we know. There still remain to be determined positively a number of facts and conditions, the most important of which is whether the organ is derived from the ectoderm (hypodermis) or mesoderm (fat-body); the conditions seem to point to the latter.

The development of additional lighting areas and tissues that takes place in the change during late larval life and the larger portion of the pupal life will next be discussed. The completed organs of the adult and their structure have already been describe in the preceding chapter; also, the fact that the thorax of the pupa shows a general glow, as has been described by McDermott, Williams, and Mr. Harry Parker. The writer has also noted it in some pupæ that were being raised in captivity. The exact source of this light should be further studied and an explanation sought.

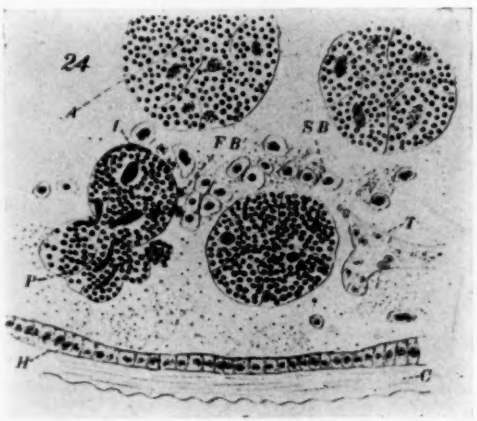
The origin of the adult male and female abdominal organs has been often looked into in a superficial manner and many surmises made concerning it by many writers. Two chief theories concerning the subject exist: First, that these organs are derived from the ectoderm, or the hypodermal cells of the integument; second, that they are derived from the mesodermal tissues by a transformation of certain of the fat-body cells; thirdly, some writers have claimed that they are derived from both of the above

sources, the reflector layer from the fat-body cells and the light-producing layer from the hypodermal cells.

Owsjannikow, Heinemann, Marchal, and Dubois have all come to the conclusion that the organ is derived from the hypodermis and the writer has found some evidence to show that it may be true. His studies are still being pursued.

Treviranus, Max Schultze, Emery, Leydig, Seaman, Wheeler, Bongardt, Berlese and Vogel, on the other hand, have understood that the fat-cells were the source of the photogenic tissues. The writer and W. A. Kepner have also published this view in a text-

FIG. 3.



Section from the ventral abdominal region of sixth or seventh segment of a larva of *Photinus consanguineus* a few days before pupation. Two upper fat-bodies at *A*; also two photogenic fat-bodies (*P*), one of which is beginning to rupture and allow the photogenic fat-cells to emerge from its ventral surface. (After F. X. Williams.)

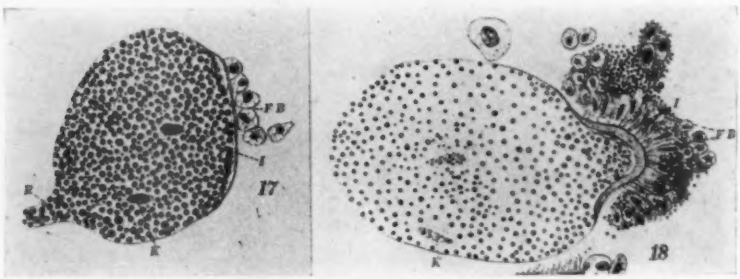
book, but solely from following some of the above writers. The best and most recent work on the subject is by F. X. Williams, who supports the idea from independent study. He expresses some small doubt, however, in his account.

Gegenbaur is responsible for the third view. Others have expressed unusual and unfounded views which are clearly a mistake: Lindemann and von Kölliker, that it is a part of the nervous system; Pierantoni, that it is a symbiotic organ in which luminous bacteria live and produce the light, and Buchner, who had much the same view. At the present time we must accept F. X. Williams's work and take the view that the entire luminous

organ is derived from the larval fat-bodies. He found the first evidences of the formation of the light-organ in a larva which outwardly showed no signs of being ready to pupate. Such signs appear several days before the change as a growing torpidity and the refusing of all food. The evidence consisted in a slight change in the appearance of the ventral fat-bodies of the sixth and seventh abdominal segments. This change consisted in a larger nucleus, a slightly deeper staining of the cytoplasmic contents, and in showing more distinct walls (Fig. 3).

The next stage is in a pupa (Williams does not state the time from pupation) and shows the growth or accumulation of a peculiar hyaline material on the dorsal surface of the fat-bodies

FIG. 4.



Two photogenic fat-bodies from pupating larva of *Photinus consanguineus*. Earlier stage (17) and later stage (18). *K*, nuclei of fat-cells; *L*, deposit or investment of hyaline material on dorsal surface of fat-body. *FB*, blood-cells which gather on investment. (After F. X. Williams.)

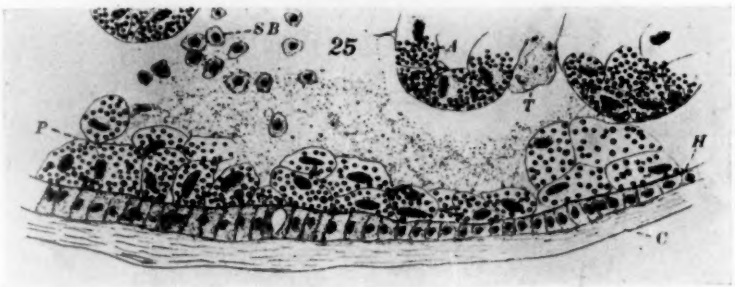
destined to form the light-organ. In section this deposit is crescentic in shape and always on the dorsal side of the fat-body, which is made up of a number of fat-cells. A number of blood-cells become attached to this investment and grow in size. This is well shown in the two stages drawn in Fig. 4, where we can also see that the blood-cells accumulate a mass of small granules of some other substance around and between their bodies. This phenomenon is not peculiar to the photogenic fat-bodies alone, but to any fat-bodies that are undergoing rapid change, and may be seen in the thorax as well, where the hæmocytes also attach themselves to the mass.

The next step is the application of some form of pressure, possibly a squeezing action by the investment, which results in the rupture of the ventral surface of the fat-body and the passage

of its constituent cells out and down to the ventral hypodermis against which they lie. The squeezing, rupture of the wall of the fat-body, and the emission of the fat-cells are well shown at *P* in Fig. 3 from Williams. The resulting deposit of fat-cells on the ventral hypodermal layer is shown in Fig. 5.

The writer would like to know a little more about the manner and means by which the light-fat-cells move from the fat-bodies down to the position they now occupy. That they are squeezed out of the fat-bodies is apparent. Does gravity cause them to assume their ventral position? Probably not, since the metamorphosing larva and pupa frequently lies on its side. The experi-

FIG. 5.



Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. *P* indicates the irregular layer of photogenic fat-cells that have been squeezed out of the photogenic fat-bodies and deposited on the ventral hypodermis; *C*, cuticle. (After F. X. Williams.)

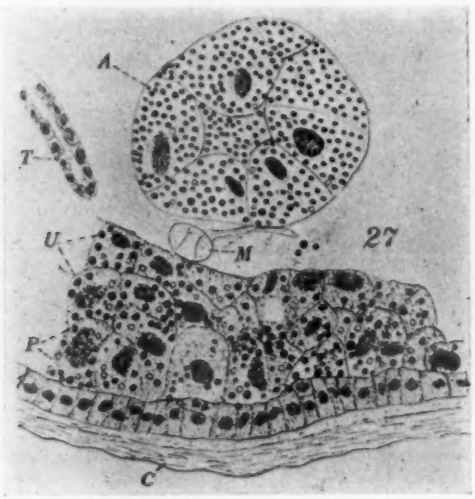
ment should be tried of forcing it to lie on its back during this stage and observing the result. The cells may have some powers of ameboid motion and attain their position by this means. They apparently move through a blood or body fluid with nothing or very little to guide them.

When first in position they are somewhat irregularly distributed and still contain the characteristic round granules of albuminous material seen in other fat-cells. Vogel describes a breaking up of these large, rounded granules of reserve matter into the photogenic granules. Williams more correctly interprets the process as a solution of these bodies to form a general food that can be used in all building of tissues, including the photogenic granules.

A number of processes now go on together. The following sketch will outline them without giving exact times of each

change with reference to the others. The future light-organ cells multiply in number and become arranged in a very regular layer instead of the more or less irregular one of the first stage. The ventral cells of the layer are first to dissolve their albuminous granules and also grow somewhat faster. Fig. 6 shows this condition after Williams. At this time the layer contains no tracheal supply, but the approaching distal ends of the tracheal channels may be seen advancing in the direction of the layer as tubes of thick,

FIG. 6.



Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. Development advanced from section seen in Fig. 5. *T*, advancing tracheal tube; *A*, fat-body; *U*, reflector-cell layer; *P*, light-cell layer; *C*, cuticle. (After F. X. Williams.)

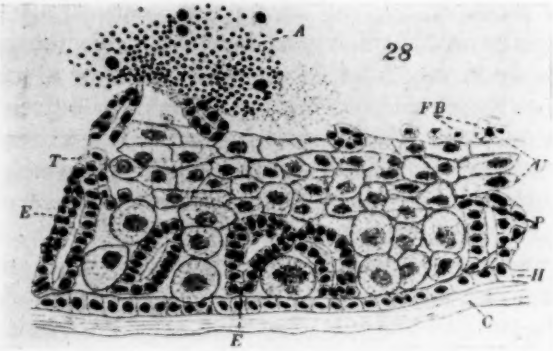
heavy cells in which the chitinous lumen is not yet developed (Fig. 6, *T*).

Fig. 7 shows a marked advance. The light-organ cells have all lost the reserve granules. The ventral layer shows cells that have advanced much in size and which are clearly becoming arranged to form the masses between which the " cylinders " will lie. Already the tracheal tubes have pushed through the upper layer which is to become the reflector layer, and now dip into the walls to form these cylinders. Their uniform epithelial walls will differentiate into ordinary flat tracheal cells and the specialized tracheal end cells that were described in the last chapter. As

yet only an opening lumen and the beginning of the chitinous channel are visible.

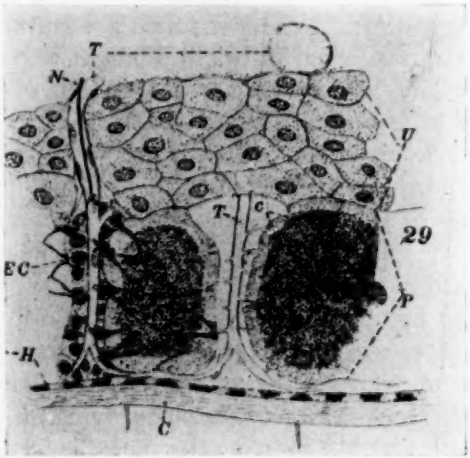
Fig. 8 shows what may be considered to be the completed

FIG. 7.



Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. Development advanced from that seen in Fig. 6. Reserve granules are all absorbed. Tracheal tubes (*T*) have penetrated light-organ to form beginning of cylinders. Letters same as in preceding figure. (After F. X. Williams.)

FIG. 8.



Transverse section of the ventral part of a light-segment of a pupa of *Photinus consanguineus*. Practically adult condition. *EC*, end-cells; *P*, light-cell layer; *N*, reflector layer; *T*, tracheal units. (After F. X. Williams.)

condition. Since it has been described before, any further description than its legend will be omitted here.

HABITS AND ECOLOGY.

The Lampyrids inhabit a great variety of situations. These localities must always be such as provide the proper food, and, in so far as we know, this food always consists of living snails or slugs. There is no form of migration so far as can be seen, and the larva probably lives all of its two years of life within a hundred yards of where it was hatched, while the adult male appears to fly in search of its mate for not over a quarter of a mile. Also, the female of most species is not so given to flying, and in some species is without that power. The writer knows of several colonies of *Photuris pennsylvanica* in the neighborhood of Princeton that are confined to areas of not over ten acres, and the larvæ are always found on this spot. During the breeding flight the insects sometimes fly a mile away, but usually fly in an irregular course over the locality itself.

The larvæ are nocturnal, as have been described for their feeding habits. The flight of the adult lasts for only a few weeks at the most, and they are not known to take any food during this whole time, their energies being devoted to mating and depositing the eggs in the proper position for the life of the future larvæ. As is true of the larvæ, the time of activity in the adult is in general the night-time. Some few forms are known to be on the wing in the daytime, even in bright sunlight at midday, as has been described by McDermott for a specimen of *Pyractomena angulata* that he captured in Washington, D. C.

Photinus scintillans has been watched for several seasons by the writer on his lawn at Princeton, N. J. This little fire-fly has a decided tinge of yellow or even orange in its flash. The males appear in latter June, at first a few stray specimens and a few days afterward great numbers, including some females, every evening. The first flashes are seen at about sunset or a little before, and these are in the grass. The insects may then be seen crawling up blades of grass, emitting the light at intervals, and, when they reach the top of the blade, flying off. At first they stay near the ground, but shortly after dark they fly at an increasingly higher level until, at 9 to 10 P.M., they are twenty feet or more up in the air. They then begin to fly irregularly and also to either stop flashing or retire to the ground for the night, for after that hour they are seen no more. They are said to come

out again at dawn, but no observations as to this fact could be found.

The females of this species are wingless and therefore do not fly. They crawl up on a blade of grass and stay there, flashing until their mate finds them. After copulation, which lasts for some hours, they go to the ground and remain there, wandering around and laying an egg here and another there until all are exhausted. The number of eggs is small, about twenty, and they seem to be all fully grown and ready for laying when the insect first hatches. The female lays them among the grass roots.

Another species, *Photuris pennsylvanica,* much larger, begins to fly later in the evening, usually at 8 P.M., or later, and flies further into the night. Both sexes are on the wing, and their strong single or double flash of an intensely greenish-yellow color is visible from six feet above the ground up to as high as the highest trees of the forest on whose edge they fly. The writer has seen a few examples of this specis flash in the darkness just before dawn. While usually local, they sometimes wander far, and have been caught a mile or more away from their "colony" and flying about with *Photinus scintillans* on the campus at Princeton.

The mode of lighting in the adult insects is varied in all these forms. Most of the species have a characteristic flash, but besides this usual flash the light often appears in other forms of glow. The characteristic flash has been best described by McDermott in several papers, and has also been studied by Mast, Lund, Fisher, Barber, and others. It is well summarized by McDermott for eight species found around Washington, D. C., in the table shown as Fig. 9. Here the flash is represented by a curve on section paper in which the abcissæ indicate time (1 cm. represents 1 second) and the ordinates show the degree of brightness (1 cm. equals 0.02 candle-power). Also, we can note here that the flash of the male is in general shorter but more intense than that of the female. In one form there is an "after-glow" following the male's flash (*Pyractomena borealis*). In *P. angulata* the male gives a series of rapid flashes. In *P. lucifera* the male gives a succession of flashes that are so rapid that it forms a single pulsating flash. The female of this species answers with a single steady flash. A glance at the diagram (Fig. 9) will serve to show better than further description the kinds of flashes used.

In the last few years it has been decided by some zoologists that practically all these flashes are mating signals. This has been proved in several cases, but is not so easy a fact to observe as some might suppose. In fact, it seems that the flashing is sometimes done entirely at random; and while searching for the

FIG. 9.

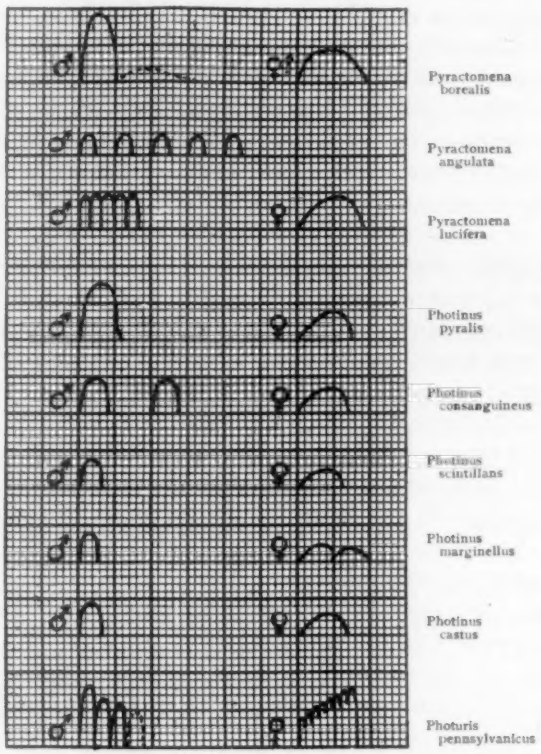


Chart to indicate the different forms of flashing used by males and females of several species of fire-flies. Distance from left to right equals time (one second to each centimetre). Distance from below upward equals intensity of light (0.02 candle-power for each centimetre). Male flashes to left, females to right. (After McDermott.)

mate, of course, the flashing goes on in such a way that its relations cannot be understood.

The work of several observers, particularly McDermott and Mast, has shown that the flash of the female is used to attract the male, while that of the male is evidently to announce his

presence. In some cases both male and female fly (*Photuris pennsylvanica*), and both sexes can be attracted to a small electric bulb, covered with a bit of thin green leaf and operated in a manner to simulate the light of the insect. Both sexes were attracted in this way and captured.

In other cases the female does not fly or cannot fly and sits on grass-blades or on the trunk of a tree and signals the male from there by her characteristic flash. McDermott has described this for *Pyractomena borealis* near Washington, D. C. Here the larvæ pupate in cracks in the bark of trees, and when hatched the female stays on the tree trunk and signals. The males answer her flash, and alighting upon the tree trunk, run about until they find her.

Mast observed a species found near Baltimore, Md., and was able to study the reactions easily. He found that they emerged and began to flash before it was dark and while one could still see well enough to read print. The females crawled up grass-blades and sat there without attempting to fly. The males flew about, flashing regularly at intervals of about five seconds. The females did not attempt to light unless first stimulated by the flash of a male near by or by a flash from some artificial source. When she did answer the flash of the male he turned and flew directly toward her. Several repeated flashes and answers were required to bring them together.

Mast decided that the flash was the only factor involved in this attraction, and that the male, no matter how near, was not drawn by either the objective sight of the female or by any odor. The writer disagrees with this in the case of *Photinus scintillans*, as he has confined them in a small vivarium and seen them come together and mate without any flashing when near enough.

Mast showed that the male is not positively phototropic to a continuous light, but only obeys a flash. The act of turning in a given direction and of flying toward the female, which he does with wonderful accuracy, is performed only a second after her flash has been seen, and is done in darkness and with no signal other than the former flash to guide him.

In certain other species the female gives off a continuous glow, to which the male, who flashes, is attracted. The best example of this is perhaps the European form, *Lamprohiza splendidula*, spoken of in the preceding section. The body of the

female is very light in color, and her numerous lights, all glowing at once, cause the whole form of the insect to shine so that the individual organs can hardly be distinguished. She crawls slowly about or lies quietly in some damp corner in the grass, and one can look over a hillside and count the individuals so lighting for several hundred yards about.

It is not always possible to definitely get a reaction by artificial means to prove this use of the light as a sex lure, nor to establish the fact from carefully watching the insects in flight. The fact had been established for *Photuris pennsylvanica* by Mast and McDermott, but the writer once went out to observe this with Dr. S. O. Mast at Beaufort, N. C., and, although hundreds of this species were flying about and both males and females were caught, the attraction lighting could not be observed Nor could any of the insects be lured with the flash of the electric hand torch. McDermott found that the light had to be shaded with a bit of green leaf or other green transparency; or, even by shading the light with the hand, the males would approach it, although the color was then reddish instead of greenish. It thus seems that the color of the light was not so important as its intensity and time.

Another factor observed in the case of *Photinus scintillans* was that of the time between flashes. Here, too, the color was altered by interposing screens of glass stained in various ways, and yet no difference appeared in the reactions. On the other hand, if the flash was timed properly, a factor that varied with the temperature of the air, the males could be lured by an electric lamp or even by striking a small match. This would not seem to be the important factor when one remembers that the light color varies in the different species.

Other methods of flashing have been observed. McDermott describes four distinct methods of flashing for *Photuris pennsylvanica*, and his observations are quoted as follows:

"Four distinct types of light-emission on the part of this species were observed, agreeing with those previously reported (*Can. Ent.*, 1910, vol. 42, pp. 358–360). First noted was a series of usually three, though sometimes four or five, rapidly repeated flashes of considerable intensity, followed by darkness for several seconds; the flashing thus was repeated at intervals of from not more than three seconds to as much as half a

minute. The series of flashes is suggestive of that of the male of *Pyractomena lucifera*, except that ordinarily not as many separate flashes are given, that there is a distinct interval of darkness between succeeding flashes in the series, and that the flashes in any series appear to be of diminishing intensity" (see diagram, Fig. 9). "The specimens which exhibited this type of flash came to the lamp when given the long flash described, and were *usually, though not always,* found to be males.

"The second type of lighting observed was that which the writer has previously described as 'a faint glow, rapidly increasing in brilliancy. . . . It then ends suddenly.' . . . The only correction to make on this earlier observation is that this flash, when observed close at hand, is seen not to be a continuous steady flash, but a series of very rapid pulsations, or a flash of very rapid variations in intensity, such as may be observed in a moving mirror image of an arc-lamp operation on an alternating current (see diagram). As compared with the phenomenon of the alternating-current arc-lamp, 'frequency' appeared to be about 50 per second, rather slower than the lamp (60 cycles). One insect flashing thus was caught on the evening of May 27 and found to be a female, but at this time none could be attracted to the electric light by imitating either this flash or that described in the preceding paragraph for the male. Later, notably on the evening of June 17, along the Chesapeake and Potomac Canal, only a few hundred yards from where the first observations were made, females giving this long flash repeatedly came to electric lights operated in the flashing manner of the male, when used both by the writer and by Mr. H. S. Barber, the bulbs in both cases being shielded by a leaf. The reverse attraction, as described in the foregoing paragraph, was also observed at this time, and had previously been observed by Mr. Barber and the writer, along the canal on the evening of June 3. There were, however, some curious exceptions: for instance, on the evening of June 5, at the writer's residence, 1901 Jackson Street, N. E., this city (Washington), an insect giving the long flash was attracted to a lamp giving the flashing light, and when captured proved to be a male; also on the evening of June 13, at the same place, seeing the electric lamp giving a long flash, two females and four males were attracted, caught and identified. It was not found necessary that either sex

be flying to respond: insects at rest on leaves and fences repeatedly responded by flashing to stimulation with the electric lamp and would sometimes leave their locations and fly to the light. Good results were never obtained unless the light was either shielded with a leaf or the bulb coated with a solution of malachite green and chlorophyll in collodion.

"The third method of lighting observed for this species was that already described as single, not very bright flashes, emitted at intervals of a second or two while the insect is flying through the air in almost any direction, dropping from a tree or running around on the ground or on the grass. In every instance these insects were found to be females. Operating the electric light in imitation of this flash did not seem to cause attraction of either sex, but in one instance, when a male was observed on a fence-rail, giving his usual triple flash, and responding to the electric-light flashes in imitation of the usual long flash of the female, the change to the type of flash above described caused him immediately to cease to respond. Provisionally we may regard this as the flash of a pregnant (or hungry) female.

"The fourth type of light-emission consists of a single, short, bright flash, repeated at intervals of about four seconds or more. This flash is the least common, and insects flashing thus were found to be males, and did not respond satisfactorily to the electric light."

In addition to the flashing as mentioned, we find cases in which fire-flies are said to flash in unison over a wide area. One writer describes a large field in which thousands of them flashed synchronously and rhythmically for a long period. Critics of this observation said that some such rhythm was apt to develop on the mathematical basis of probability and chance in any medium large grouping of such individual phenomena. The observation seems to have been confirmed, however, and established as an occasional fact. Prof. Henry Jones Ford related to the writer his observations of some tropical fire-flies seen along the Cotabato River, in Mindanao, Philippine Islands, one night in April. These insects congregated in a few isolated trees of a certain unknown variety and were found only in such trees. They seemed innumerable in each tree as it was passed in the night by the river steamer, and they were all flashing rhythmically and in unison.

There are other and abnormal methods of lighting commonly

seen in the flashing varieties of fire-flies. Whenever one is captured by a spider or in a spider-net, it at once turns on the steady, somewhat weak glow that one sees in the larva. This emanates from the adult organ, the same that is used at other times for flashing. This same steady glow also shows as a trace or after-glow, coming immediately after the flash in the male of *Pyractomena borealis*. It may also be produced by administering various drugs or by injuring the animal seriously.

LOCALIZATION OF THE LIGHT IN THE ORGAN.

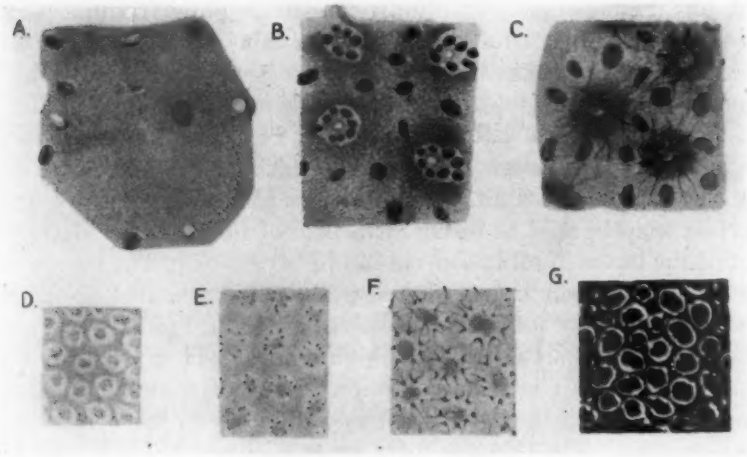
On casually observing the light from the organs of fire-flies one has the impression of a uniform, steady glow from all parts of the outer surface of this organ. And this idea seems to be true of the organ in certain species and in the larval organs; also, it is true of the light-organs of the elaterid beetle, *Pyrophorus*. Certainly all of the light-cells glow together (except in certain pathological cases), although all regions of each cell may not give off the same amount of light. This uniform glow of the entire organ surface may be said to be characteristic of not only the elaterids but of the larvæ of all Lampyrids and Phengodes. The reason of the steady, long-continued glow is a less perfect control, so far as speed is concerned, of the admission of air to the light-tissues, and this, in turn, is due to the lack of highly-developed end-cells on the tracheal twigs. The same condition is true of some adult Lampyrids which emit the light as a steady and more or less continuous illumination. The females of *Lamprohiza splendidula* and all species of *Phengodes* are good examples of this condition.

On the other hand, we find many adult Lampyrids in which, as is described on another page, the light appears in short, quick flashes. If such an insect is looked at casually while lighting it appears as if the light came from the entire surface of the organ, but if one examines this surface more closely, especially with a low-power microscope or a hand-lens, it is at once seen that the luminous areas consist of a series of circles. Emery and Lund have well described this, and Fig. 10, A, is copied from Emery's paper on the subject. In this figure the lighted surface (*G*) is compared with sections of the organ fixed and stained in various ways, and we can see that the rings of light correspond with the edges of the luminous tissue where it is in contact with the end-cells. *G* represents the beginning of a flash or of a weak glow of light. When

the glow is stronger or at the height of the flash the outer limits of each ring are extended as the oxygen comes in through the tracheoles and penetrates deeper into the masses of light-cells, until, during a strong illumination, we see a luminous field with circular areas that remain unlighted or only partly lighted by reflected light.

In some few flashing forms, such as the Japanese species *Luciola vitticollis* and *Luciola parva*, we do not see any such circles, because the cylinders are not present.

FIG. 10, A–F.



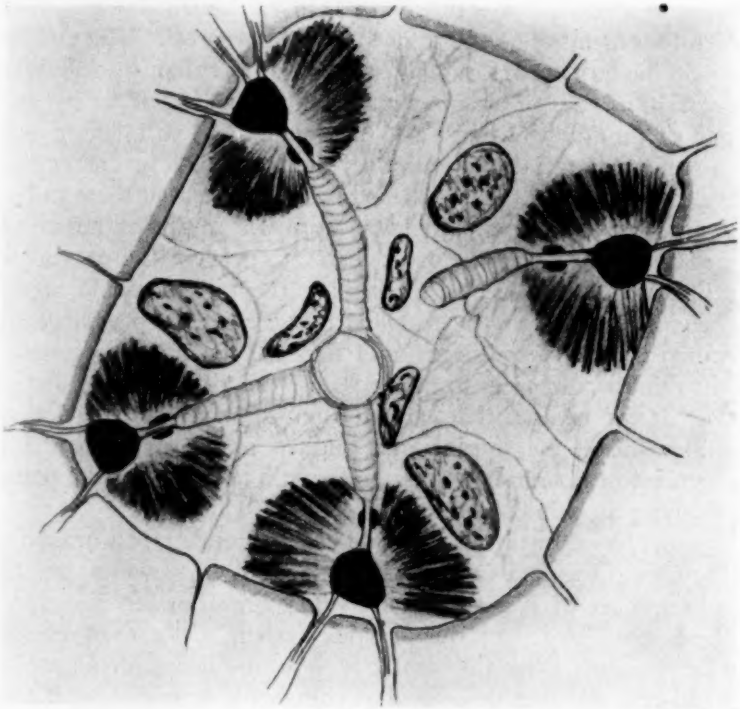
A–F, Figures of horizontal sections of light-organs of *Luciola italica* to show results of various methods of fixation and staining. *G*, view of surface of organ of same insect to show rings of lighting. (After Carlo Emery.)

Lund further localized the light as beginning in the regions of luminous cells lying in the angles formed by the branching of the tracheoles as they emerge from the end-cells. These points of light immediately spread to form the circles, and then the circles' enlarged and diffused light acted to render the whole surface uniformly bright.

If a fire-fly is cut in two or the last segments bearing the light-organ are clipped off with a pair of scissors, there is a flash, a glow, and then the organ gets dark. If we now raise the temperature slowly, a weak glow begins to appear at about 125° F., and this grows brighter until at near 190° F. the light suddenly

dies out. In order to understand the immediate physiology that underlies these different kinds of flashes we must refer briefly to certain features of the structure of the organ. The masses of light-cells containing the granules of photogenin are supplied on most of their surfaces with tracheal end-cells that give off fine

FIG. 11.



Portion of a horizontal section of the light-cell layer of *Photinus consanguineus*. Shows one cylinder containing a tracheal unit in cross-section and four end-cells, edges only of the light-cells shown. Three of the end-cells show their large nuclei. Three tracheal epithelial nuclei also appear. Note the radial bodies, the small cylinder bodies, and the large distal rounded bodies from which the tracheoles emerge. These latter are only shown for a short part of their length as they pass between the light-cells. (Original drawing.)

tracheal capillaries which penetrate to all portions of the mass. These tracheoles, in *Photinus consanguineus* at least, pass between the cells. Air is supplied by tracheal stems that carry it from the larger trachea to which it comes from the stigmata opening from the outside edges of the segments. It is evident that the

tracheal end-cells are the key to an understanding of the process.

Fig. 20 in the preceding part of this work shows the structure of one of these end-cells in *Photonus marginellus*, and Fig. 11 of this part is another and perhaps a better figure to show the end-cells in correctly-fixed and stained horizontal sections of the light-organ of the fire-fly *Photinus consanguineus*. Here it may be seen that the tracheal twig enters the cell and, having contracted to a very narrow tube, it ends in a cylindrical organ, from which two or more of the tracheoles are given off. The end-cell bears in the larger part of its distal body a peculiar specialization consisting of rods of a denser material that radiate from the end-organ of the tracheal twig; also, a rounded and still denser mass of a similar material that embraces the tracheoles just after they leave the end-organ. It is believed by the writer that these radiating rods and the rounded mass represent muscular structures which are of two possible uses: First, to prevent the passage of air into the tracheole by compressing them; this would appear to be the function of the rounded mass; second, to enlarge the terminal twig and end-organ and thus fill it with a new supply of air; this would seem to be a possible function of the radiating rods. It can be seen that a rapid alternation of the two actions would result in the forcing of a sudden jet of air bearing free oxygen into the light-cell mass and would account for the power of flashing as exhibited by the organ.

Geipel has shown that each end-cell is supplied by a branch of nerve-fibre (Fig. 22 in last chapter), and this would put the whole number of end-cells in the whole organ under direct control of some centre in the nervous system. We need further studies to show what this centre is, how the nerve terminates in the end-cell, and just what kind of contractile material the radiating rods and heavy mass that surrounds the bases of the tracheoles are composed of. It seems probable that two sorts of nerve supply are needed to account for the various operations of the organ: one to open the terminal twig and fill it with air, and another to compress the rounded body or constrictor and force a jet of air into contact with all light cells.

We would then be in a position to explain the steady glow that comes under abnormal conditions. When captured or injured the muscles would all be relaxed and a steady glow would result from the slow and steady invasion of air; also, when the

excised abdomen was heated, the muscular control would be relaxed and the same result be attained. We know that the end-cells of the larva and of some allied forms do not show these muscle-like structures and can thus explain the steady glow and lack of flashing power that they exhibit.

In further reading and assembling the facts concerning the manner of lighting of fire-flies and the conditions under which the light may appear we find some difficulty in considering whether the results obtained and observed are due to physiological factors of nerve-muscle action and mechanical factors or to purely chemical factors by which the light is produced. It seems possible to separate them fairly well through a careful study of the experimental work of many writers, particularly that of Pfluger, Macaire, Bellesme, Kölliker, Heinemann, Dubois, Bongardt, Carradori, Watasi, Townsend, Kastle, McDermott, Lund, and E. N. Harvey. Such a review will reveal many possibilities as to future profitable experiment and observations. It will be best to first separate out the factors which appear to be purely physiological so far as possible, and reserve the more strictly chemical side for the chapter in the general chemical discussion of all the organisms which will follow. It is unavoidable that the two subjects should be somewhat entangled, however.

MECHANICAL.

We have already seen how the injury of the fire-fly will cause the light-organ to glow. Kastle and McDermott have described it and shown that the organ at once flashes and then slowly becomes dark. If the light-centre is in the brain, the flash would be explained by a sudden removal of the nervous inhibition which causes the muscle mass to contract violently, force air through the tracheoles and into the light-organ; the following darkness would also be explained by the lack of motor supply to again open up the end-cell terminal organ and admit a nerve supply.

Several authors have now shown that if the decapitated animal is allowed to rest it recovers from something (shock?), and if stimulated mechanically the organ begins to glow steadily again, perhaps over its entire surface or perhaps only on a part of this surface, depending somewhat on the nature and extent of the stimulus applied. Such stimulus undoubtedly acts on the organ through its nerve supply, and there must be a motor-centre in

one or more of the lower ganglia through which the action takes place. McDermott found that such slight stimuli as tapping with a pin or match-stick or dropping to the floor would cause the quiescent organ to glow. Undoubtedly these very slight mechanical shocks worked through the nervous supply. In these cases the organ had been clipped off just anteriorly to its margin, so the motor ganglia were probably in the abdominal region.

While the above instances were cases that had no abnormal relation to the chemistry of the processes, there are others that have. If the light tissues themselves are cut or torn, air is admitted directly to the cells and we see a steady glow. This glow persists for a time and slowly dies out, owing to the fact that the exposed surfaces are exhausted and they then protect inner and unexposed parts from a further penetration of the oxygen. The ultimate case is when the organ is crushed and smeared between the fingers. Even then certain parts of the mass remain protected by outer artificial surfaces. If the crushed organ is again smeared between thumb and fingers it again glows, since new and unexhausted parts are exposed. The organ can be exhausted in an unwounded insect, as was shown by Tilesius and Meyen, by repeated mechanical stimuli. In this case two factors enter. First, the muscles (end-ceil fibrils) that control the air flow may become fatigued, or secondly, either of the light-producing substances may be exhausted, either permanently or for the time being. The former is probably true in most of the experiments that have been tried. It would probably take a long time to exhaust the luciferine or luciferase (photogenin or photophelein). McDermott states, however, that a detached organ that cannot be made to light by simple percussion cannot be made to light in any other way.

TEMPERATURE.

When higher temperatures are applied to a decapitated insect or excised organ that is quiescent the light will appear and the organs begin to glow. Macaire observed that the light was extinguished above 52° C. and under 12.5° C. His experiments showed that the light which was extinguished under 12.5° C. reappeared at 27.5° C., and at 41.3° C. it was strongest. When it was raised to 57.5° C. it went out again, and if it continued to raise to 63° C. it could not be restored. The first part of these

experiments has to do with nerve and muscle activity, while the last experiment shows (as Harvey's work bears out) that one of the two chemical substances was destroyed. The other will resist still higher temperatures and operate again when the other is supplied.

ELECTRICITY.

Electric shock will cause a living fire-fly to glow or flash, and work has been done on this line by Macaire, Jausset de Bellesme, Kölliker, and others. The shock applied to the living animal results in a flash or glow, according to the particular nerve-centre that has been stimulated.

Such electric stimulation has no effect whatever upon the chemical processes in the light-cells themselves, apart from the above stimulation through the nerve control. Experiments by E. N. Harvey have shown this conclusively, especially on organs in which the tissues have been killed by drying, thus separating the light materials from their influence entirely. Macaire also observed that so long as the tissues lived the electric current caused them to glow, but that the moment they were dead (as evidenced by an opaque color due to proteid coagulation) the effect stopped. Pfluger found that the electric spark would evoke the light in a living animal, but that the continuous current would not except at the make-and-break of this current.

PRESSURE OF AIR OR OXYGEN.

All investigators from Boyle down have found that, when placed in a vacuum or in hydrogen gas or some gas other than one bearing free oxygen, all attempts to evoke light from living or dead fire-flies was a failure, and that when the air or some free oxygen was then readmitted the lighting power was resumed.

Besides stimulating the organ through its nerve supply, Lund experimented with air pressure. He first applied direct pressure to the body in an unwounded insect and obtained a flash. This might have meant either a mechanical supply of air or a stimulation through nerve supply. He then cut off the organ and placed it in a sealed tube to which a moderate sized rubber bulb was attached so as to force air into the tube by a pressure of the hand. When the organ was quiet and inert he squeezed the bulb and obtained a flash or glow in some proportion to the pressure. This indicates that air was actually forced from the trachea into the

light tissues. Such an artificial flash is almost as bright as the natural one. The same fact held true when portions of the organ were experimented with in the tube.

Lund points out that this phenomenon is partly controlled by another factor. Pressure applied as above may drive some air into the tracheoles, but it also increases the oxygen concentration and in that way makes the light brighter. The presence of free oxygen is a *sine qua non* of the reaction. More work on this subject is needed but will be difficult.

The chemistry of the light-process has been studied by a number of writers, the latest and most careful of whom are Dubois, Lund, McDermott, and E. N. Harvey. While a further and complete account of the reactions will be given under the chapter on the general chemistry of light production, we may sum up here a few of the principal facts. The granules of light-producing substance (luciferine of Dubois) are found in the light-cells of the organ. Harvey has called these granules photogenin. They are quite soluble in water in the fresh condition, but when coagulated by fixatives, become insoluble; they are doubtless much changed by the fixation. When in solution the substance is fairly stable. It is destroyed or changed so that it will no longer light after being exposed to a temperature of 42° C. It is not soluble in ether nor any of the fat-dissolving fluids. There is a larger amount of it in the body than of the assisting medium, called by implication luciferase (Dubois) in the fire-fly and renamed photophelein by Harvey on account of important mistakes which Dubois made while describing the light-producing substances in Pholas dactylus. Thus we can isolate or free photogenin from photophelein by allowing the two to react on one another in a free aqueous mixture. Under these circumstances the photophelein is exhausted and we have a surplus or residue of photogenin left with which to work.

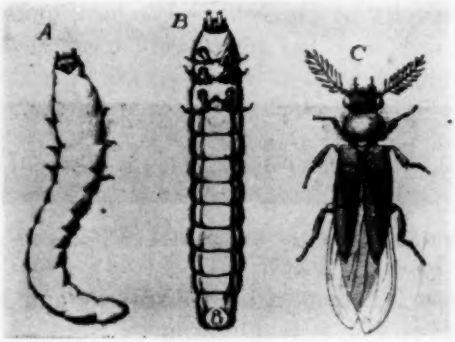
The photophelein is probably in a fluid form and is found all through the tissues of the body. It is also found, or something like it, all through the tissues of the body of other, non-luminous insects or even other groups of animals, so it is not for use with photogenin alone, but produces other vital reactions in the body of the fire-fly, in all probability. The problem of the exact nature of these two substances, the proteid-like photogenin and oxidase-like photophelein, and how they operate, together with oxygen in

the presence of water to produce so efficient light, is one of the most attractive problems in biology.

PHENGODES.

Allied to the Lampyrids, and by some included in the group, are a number of beetles that give light from a large number of organs and show a female of very primitive adult development. These insects are found in both North and South America and are not abundant in any locality. In many cases we know only the male or the female and can connect neither of them with the other sex or with the larval stage. In a forthcoming paper Mr. Barber, of the U. S. Bureau of Entomology, will give us the

FIG. 12.



Larva (*A*), adult female (*B*), and adult male of *Phengodes laticollis*. (After Henneguy.)

latest *résumé* of the groups with what is known of their structures and habits.

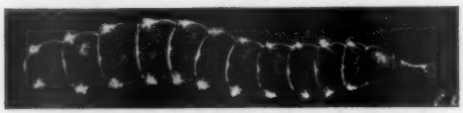
Of the North American, species the best known, perhaps, is *Phengodes laticollis,* found near the eastern coast from Massachusetts to the South. Fig. 12 shows the adult male and female and the larva as pictured by Henneguy. *Phengodes longicornis,* Barber, is another eastern species which is perhaps not so rare. The males of these forms are said to give no light, while the females and larvæ, which resemble each other superficially, are among our most brilliant forms, giving off a bright greenish light from eleven of their segments, one organ on each side of the segment, or twenty-two in all.

A few of these insects are captured each year by entomologists,

but they are unknown to the majority of those interested in natural history. Their luminous organs remain undescribed, but they probably resemble those of the lampyrids to a large extent. The larvæ and the apterous females hide under stones and boards, but on warm, wet nights in the breeding season (June) the females emerge and display their light to attract the males. The males fly and have large, keen eyes with which to find the lighted females. This method of seeking each other reminds one much of the habits of *Lampyris splendidula* of Europe as described on a preceding page. Fig. 13 shows the position and appearance of the lights on the illuminated female of *Phengodes laticollis* as shown by Henneguy.

Besides the North American species, those in South America are much more numerous and of perhaps greater interest on account of the color of the lights. We have quite a history, al-

FIG. 13.



Appearance of adult female of *Phengodes laticollis* when she is using her light-organs. (After Henneguy.)

though an imperfect one, of their discovery and study. Azara, in 1809, describes a larva from Paraguay from whose sides rows of light shone, while from the head a red light like a glowing coal was seen to appear. Reinhardt, in 1854, made the same observation, securing his specimen from a bit of rotting wood in Lagoa Santa. The side lights were greenish and intermittent, while the red light was more constant. The larva was 40 millimetres long and appears to have been the apterous female. Its predatory nature was indicated by its formidable mandibles like pincers.

A. Murray, in 1868, described to the Linnæan Society in London a similar larva which he named *Astraptor illuminator*. This was probably another species of the same genus. Fry described another specimen from Rio de Janeiro. Agilvia described another specimen from Montevideo that was two inches long.

The well-known entomologist, Burmeister, in 1875, described the same sort of insect from Parana, in Argentina, in the month

of August. This also showed the red and green lights and was undoubtedly one of the same genus, if not species. It was found in rotted wood in a forest. It was very lively and aggressive and fought its captor. In December, 1870, Weyenbergh found one of these creatures in a street of Cordoba (Argentina), in the evening, during a heavy rain. He described the side lights as bluish-white and the head light as bright red. Since he described various brown lines and spots on its back, this was probably an adult female. Dr. von Ihring also described one two inches long from Rio Grande de Sol, in Brazil; also, Dr. Alphons Stübel, of Dresden, collected one from Popayan, at an elevation of 2500 metres.

Several other writers have described elongate larvæ with side lights which seem to belong to one of the many species of *Pyrophorus*. There may be, of course, larvæ of Phengodes in South America that lack the red head light, but those from the southern parts of the continent always appear to have it and to be members of the genus Phengodes. Dr. Erich Haase, of Dresden, was so fortunate as to find a pair in copulation and to secure eggs from the female. These eggs hatched and the resulting larvæ lived for eighteen days. Dr. Hieronymus also found such a pair in Cordoba, and thus we are able to describe and know the forms of at least one species, which Haase named *Phengodes hieronymii*. The young larvæ had the greenish side lights and also the red head light, and the female was apterous and with the same lights as the larvæ, which she much resembled. The eggs were light-brown, and round, with a diameter of almost two millimetres, and were not luminous.

The male had light-organs on his ventral posterior abdomen, so here we find a Phengodes species whose male can illuminate. The female and the larvæ all had the characteristic greenish side lights and red head lights, even as the latter emerged from the egg. Besides the many Phengodes species, there are allied forms in South America belonging to another genus *Zarhipis*.

BRYOZOA.

We have as yet only uncertain reports of luminosity in Bryozoöns. In some cases the light has been traced to microscopic organisms that infested them, much as has already been shown to be the case for certain sponges.

There still remain reports, however, which should be followed up by careful research, by Molisch (*Membranipora pilosa*), Landsborough (*Flustra pilosa, F. membranacea*), Ehrenberg (a *Retepora*), and Gadean de Kerville (*Scrupocellaria reptans*).

Landsborough's work seems to be a reliable bit of somewhat superficial observation. He took leaves of the sea-weed *Fucus serratus* into the house and, noticing that they sparkled when touched, he tried to locate the flashes. These appeared to emanate from the tiny zoöphytes that are so commonly found on these leaves, and among them was *Flustra pilosa* and *F. membranacea,* as well as many hydroids. When shaken, the polyps gave off much light from all over their heads and stems. This light clung to the hand, indicating an external discharge. It also appeared to come from as many points on the surface as there were cells, as he puts it.

In favor of there being an autogenous light in these forms is the fact that it appeared upon stimulation and was given off; also, that it came from head as well as stem. Then, too, so many of these small marine forms possess the power. Against it is the fact that such organisms are always found to have hundreds of bacteria and protozoa as well as diatoms growing on their stems (but seldom on the head). Bacteria, of course, would shine steadily, while the one-celled protozoa and diatoms would respond to stimulation by a flash as seen. On the whole, it seems probable that the observation will prove to have been correct, although not carried out in a proper scientific manner.

ENTEROPNENSTA.

The great photozoölogist, Panceri, was the first to discover that some of the species of *Balanoglossus* lighted. He first saw the phenomenon in *Balanoglossus minutus* at Naples and described and figured it. He also cut sections and pointed out certain flask-shaped, unicellular glands as the source of the light.

Hans Molisch, while working at Trieste, with Cori, also saw the light in some of the species of this genus. Still other zoölogists have mentioned seeing this light to the writer, and have agreed that it is a weak greenish-white in color.

Dr. William Crozier, of the Bermuda Biological Station, has recently been studying the luminosity of these forms and has very kindly assisted the writer by sending him descriptions, figures,

and preserved material. The form in which Doctor Crozier has seen the light to best advantage is a small species, probably *Ptychodena bahamensis,* Spengel, and they were dug out of the sand and placed in an aquarium in the station, where they were crawling about on the sandy bottom. In the evening, when the room was dark, a sharp tap on the glass side of the aquarium was sufficient to start them to lighting.

FIG. 14.

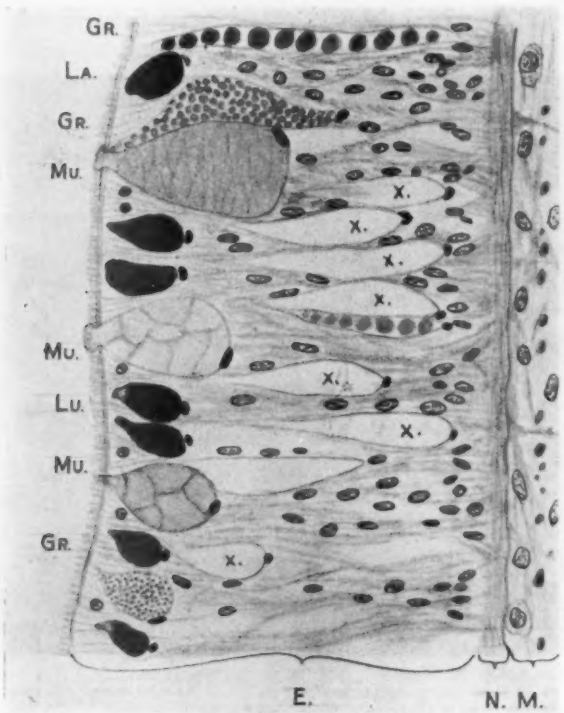
Appearance of three living specimens of *Ptychodena bahamensis* as they appeared in the aquarium at Bermuda on a dark night when stimulated by rapping on the glass. The light appears in encircling bands at various points on the body. Some slime, mixed with the luminous material, appears partly stripped off in one specimen. (Copied from a drawing by Dr. William Crozier, of the Bermuda Aquarium.)

The light appeared in one or more irregular bands around almost any portion of the body. Fig. 14 shows this clearly and is copied from a sketch made by Doctor Crozier while observing the living animals. The light is evidently an external discharge from epithelial glands, and the luciferine is mixed with some ordinary slime, so that it makes a viscous coating that can be stripped off from the skin on which it lies. In fact, it comes off without any aid, and in the figure, a portion of one of the bands

may be seen partly loosened from the body. We have no data as to how often the light can be made to appear.

Sections of all parts of the body have been cut by the writer, and it was easy to see just how the lighting is accomplished. The body is everywhere covered by a deep, simple epithelium

FIG. 15.



View of a portion of a section of the body epithelium of *Ptychodena bahamensis* from just below the collar. *M*, muscle layer of integument; *N*, nerve-plexus in base of epithelium. Basement membrane is line dividing the two preceding zones. *E*, epithelium proper; *Lu*, luminous cells; *Gr*, granule cells with granules of different sizes in different cells; *Mu*, mucous cells; *X*, cells of unknown function whose contents have dissolved out in preparation. (Original drawing.)

whose elongate cells show an amount of differentiation comparable to that found in the higher worms and more highly organized Cœlenterates. Fig. 15 shows a view of a portion of this epithelium from the body at a point some distance below the collar. A definite and strong basement membrane (between *N* and *M*) is seen on which the bases of all cells rest. Interwoven on this mem-

brane and forming a shallow layer (about one-twelfth the thickness of the entire epithelium) is a mass of fine fibrils which are in all probability mostly nerve-fibrils (*N*). Reaching outward from this layer are the cell-bodies of the epithelial cells, which for the most part are thin proximally and thicker distilly, so that a great many open spaces are seen in the proximal half or two-thirds of the layer. The greater part of the heavy secreting bodies of cytoplasm are seen in the distal portion of the epithelium. The outer ends of the cells form a straight, even line bearing short cilia that is broken here and there by the duct-like openings of the secreting cells. The cilia emerge from a striated border whose two boundaries form a double contour in which terminal bars are used to cement the cells together.

It is almost impossible to separate the cells or trace their individual outlines accurately, since so many of their bodies are very thin and irregularly shaped. The nuclei are very variable in size and appearance. We will classify and describe these cells with reference to the masses of secretion that we find, for the most part, in their distal ends.

Plainest of all and very numerous are the mucous cells (*Mu*). In iron hæmatoxylin stain their contents are quite transparent and do not stain. When mucin stains are used, as in the specimen drawn, the secretion stains darkly and shows the characteristic heavy reticulum of such cells in all animals when the mucigen granules are partly dissolved by water (see Fig. 15, *Mu*). The nuclei of these cells are large and rest well down toward the basal region.

The second type of cell (*Lu*) is taken by the writer to be the real light-cell. Its secretion forms a round, oval, or pear-shaped mass in the distal region, and the nucleus lies just proximal to and almost touching the secretion mass, which is often dented to partly enclose it. This secretion mass is pale yellow in life and also a slightly darker yellow in the sections stained with Delafield's hæmatoxylin or other mucous stains. When stained with iron hæmatoxylin and decolorized, as is usual in that method, the light-mass takes a deep black, while the mucous masses remain unstained. The distal end of the mass is pointed and near to its outlet. Often this distal end is light-staining and irregular. In most stains the mass appears to be homogeneous, but in deeply and clearly stained slides one can see that it is composed

of fairly large granules closely pressed together or even only partly separated one from the other. These cells appear to be the luminous cells and their enclosed secretion the photogenin.

The third type of cell (*Gr*) contains as its secretion a mass of large granules. In staining reaction they resemble the last kind, but when fresh or decolorized they are transparent and almost invisible. Such cells are not as numerous as the former, but they are fairly well scattered over the whole body; also, the secretion mass is long and spindle-shaped, and extends down pretty well toward the proximal end of the cell. Some of them contain much smaller granules than others, and this may represent developmental stages. It seems possible that such cells may represent early stages of the mucous cells, as these stages have been described by Schneider in the case of the earthworm and other invertebrates. In Fig. 15, *Gr* represents this kind of structure.

One more cell remains to be accounted for. Its secretion mass is represented by a deep-lying vacuole, for the contents have all been dissolved out. We can only guess at the function. It may have been a fat that dissolved in the alcohol or xylol of clearing, or a watery fluid that was removed already at the time of clearing. Such cells are seen in Fig. 15, *X*. The nucleus is small and compact and is always lying against the proximal end of the spindle-shaped secretion vacuole. It is usually forced into a triangular shape by this contact. Like most of the other gland-cell nuclei, it is small, compact, and dark-staining. The nucleii of the undifferentiated epithelial cells are larger and more open in structure.

(*To be continued.*)

Dangers of Paper Fractional Currency. ANON. (*Revue Scientifique*, vol. 55, No. 4, February 3–10, 1917.)—Paper money of the small denominations of 50 centimes, one franc, and two francs, issued in the French provinces in consequence of a shortage of coin, have been found to be a very convenient medium of exchange, but unfortunately they become rapidly soiled and coated with germ-bearing matter. Analyses made by the municipal laboratory of Rouen show that this fractional currency, carrying but one per cent. of fatty matter when new (printing ink), in the course of many handlings rapidly accumulates fatty material to the amount of ten per cent. The danger of infection from this heavy coating of germ-bearing material is aggravated by the temptation to moisten the fingers with saliva in handling these notes.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DURABILITY OF CEMENT DRAIN TILE AND CONCRETE IN ALKALI SOILS.[1]

BY

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Portland Cement Association

[ABSTRACT.]

THE use of concrete, particularly for drainage structures, in soils containing quantities of alkalies found in the arid regions of the United States has been restricted because of lack of confidence on the part of some engineers as to its durability.

Several millions of dollars are being spent annually in the construction of engineering works in these regions, and appreciable savings could be had if concrete could be used without restriction. There are many localities in these regions in which concrete construction has proved durable and satisfactory, but in others disintegration has occurred, resulting in a prejudice against its further use. Concrete is often the most economical available structural material, and therefore a comprehensive investigation of its durability is of much importance to these localities.

This investigation is conducted in coöperation with the U. S. Reclamation Service, Drainage Division of the Department of Agriculture, and the Portland Cement Association.

It comprises the manufacture of 9000 cement drain tile of 20 different varieties and many concrete blocks, their shipment to

* Communicated by the Director.

[1] Technologic Paper No. 95.

projects in Colorado, Wyoming, Montana, Utah, Washington, South Dakota, Nevada, Arizona, and New Mexico, and to fresh-water projects in Minnesota and Missouri, and their installation in operating drains and seeped areas in districts where the alkali is greatly concentrated and in most cases where concrete failures were reported to have occurred.

Included in these varieties of tile were mixtures ranging from one part cement to one and one-half parts sand to one cement

FIG. 1

Cement tile removed from drain near Grand Junction, Col., after three years' exposure to strongly alkaline drainage water. From left to right, Nos. 1, 3, and 4 are machine-made tile, plastic consistency, proportions 1 part cement to 4 parts sand. No. 2 is hand-moulded, plastic consistency, proportion 1 part cement to 2½ parts sand.

to four parts sand, both machine and hand-made, and cured in steam and by sprinkling with water. Practically all types and mixtures, commonly used in the humid region are represented, as well as others of greater wall thickness and wetter consistencies than can be made by most commercial tile machines. No special compounds or treatments have been used up to this time, except that one series each of tile were dipped in cement grout, another in hot tar, while ferrous sulphate was added to the mixing water of a third.

Concrete blocks or short columns were moulded at Denver, using the proportions 1 : 1.5 : 3 and 1 : 2.5 : 5, and a complete set of blocks were sent to eight projects of the Reclamation Service for installation in the most highly alkaline waters available on each. In addition, similar blocks were moulded on each project, using local materials, which were installed with the Denver blocks.

Crushing tests of the cement drain tile have been made yearly for the past three years, using a portable tile testing machine which can be set up at the site of the drain. The concrete blocks are inspected yearly, and signs of disintegration are carefully noted. Where disintegration has occurred, additional blocks have been moulded after special treatment of the aggregates.

Samples of alkalies, soils, and drainage waters have been collected and analyzed at intervals.

While complete conclusions as to the durability of cement drain tile and concrete in alkali soils similar to those included in this investigation cannot yet be drawn, the results of tests and observations to date may be summed up as follows:

1. CONCRETE.

Concrete which is to be placed in alkali soils should be made of selected and tested materials so proportioned as to produce a dense concrete. As small an amount of mixing water should be used as will allow the mass to be properly placed. Unless these precautions are taken the resistance of the concrete to alkali action will be reduced.

2. DRAIN TILE.

The following conclusions may be drawn for the use of cement drain tile exposed to soils or waters containing alkali salts in quantities of 0.1 per cent. or more:

1. The use of cement tile in soils containing alkali salts in large quantities is experimental.

2. Porous tile due to the use of lean mixtures or relatively dry consistencies are subject to disintegration.

3. Some dense tile are under certain conditions subject to surface disintegration.

4. Disintegration is manifested by physical disruption caused by the expansion resulting from the crystallization of salts in the

pores and by softening, resulting from chemical action of the solutions with the constituents of the cement.

5. While results obtained will not permit of a definite statement as to the relative effect of the various constituents of the salts, indications are that the greater the quantity of sulphate and magnesium present and the greater the total concentration of salts, the greater will be the disintegrating effect.

6. Tile made by the process commonly used, which allows the removal of forms immediately after casting are subjects to disintegration where exposed to soils or waters containing one-tenth per cent. or more alkali salts similar in composition to those encountered in this investigation.

7. The hand-tamped tile of plastic consistency as made in this investigation are not equal in quality to machine-made tile of the same mixture, and they do not resist alkali action as well.

8. Steam-cured tile show no greater resistance to alkali action than tile which are cured by systematic sprinkling with water.

9. Tile made of sand-cement have less resistance to alkali action than tile made of Portland cement of the same proportions.

10. The tar coating as used is not effective in preventing the absorption of alkali salts from the soil.

11. The cement grout coating is not effective in preventing the absorption of alkali salts from the soil.

12. No advantage is found in introducing ferrous sulphate into the cement mixture.

If cement drain tile are to be used in alkali soils or water containing 0.1 per cent. or more of salts, similar in composition to those encountered in this investigation, they should be made of good quality aggregate in proportions of not less than one part Portland cement to three parts aggregate. The consistency should preferably be quaking, which has proved the most resistant of all mixtures used. This is wetter than that generally used in commercial tile plants and will probably require the retention of the tile in the moulds for several hours, unless some means are found to hasten the hardening of the cement.

This paper is now in press and copies will be furnished when issued to those who apply to the Bureau of Standards, Washington, D. C.

GLASSES FOR PROTECTING THE EYES FROM INJURIOUS RADIATIONS.*

By W. W. Coblentz and W. B. Emerson.

THE object of the present paper is to give the general characteristics of certain newly-developed glasses sometimes used for protecting the eye from radiant energy, especially the infra-red or so-called heat rays. Because of the difficulty in reproducing the same color in different melts, no attempt is made to give specific data on the transmission for a given thickness of glass. In order to obtain exact data it is necessary to examine samples from each melt.

These data are representative of an extensive group of glasses available for protecting the eye from (1) the ultra-violet, (2) the visible, and (3) the infra-red rays.

For protecting the eye from ultra-violet light, black, amber, green, greenish-yellow, and red glasses are efficient. Spectacles made of white glass afford some protection from the extreme ultra-violet rays which come from mercury-in-quartz lamps and from electric arcs between iron, copper, or carbon. The vapors from these arcs emit but little infra-red radiation in comparison with the amount emitted in the visible and in the ultra-violet.

For shielding the eye from infra-red rays, deep black, yellowish-green, sage-green, gold-plated, and bluish-green glasses are efficient. For working near furnaces of molten iron or glass if considerable light is needed, a light bluish-green or sage-green glass is efficient in obstructing the infra-red rays. For working molten quartz, operating oxy-acetylene or electric welding apparatus, or other intense sources of light, it is important to wear the darkest glasses one can use, whether black, green (including gold-plated glasses), or yellowish-green, in order to obstruct not only the infra-red but also the visible and the ultra-violet rays.

Data are given showing that of the infra-red rays emitted by a furnace heated to 1000 to 1100° C. (1) about 99 per cent. are obstructed by gold-plated glasses, (2) about 95 per cent. by sage-green or bluish-green glasses, (3) about 80 per cent. by very deep black glasses, and (4) about 60 per cent. by greenish-yellow glasses.

At higher temperatures these data would be somewhat different, but not sufficiently so to modify the rough estimates dealt with in this paper.

* Technologic Paper No. 93.

AN "AVERAGE EYE" FOR HETEROCHROMATIC PHOTOMETRY, AND A COMPARISON OF A FLICKER AND AN EQUALITY-OF-BRIGHTNESS PHOTOMETER.*

By E. C. Crittenden and F. K. Richtmyer.

[ABSTRACT.]

THE comparison of lights of different colors is supposed to be based on an "average normal eye." This paper records an attempt to approximate the results of such an eye with typical color differences by using a large number of observers. In particular, results obtained by a flicker photometer and by an equality-of-brightness photometer, with different degrees of color difference, are compared. In terms of the Ives-Kingsbury test solutions, for which the proposed normal ratio of transmissions (with a 4 wpc. carbon lamp) is 1.00, the average of 114 observers gives a ratio of 0.99. By using these test solutions results obtained on the flicker photometer by a small number of observers can be corrected so as give normal values with a high degree of accuracy. On the average, equality-of-brightness measurements also vary in proportion to the test ratio, but erratic variations often overshadow these systematic differences. For sources having relatively high intensity in the blue, flicker values tend to fall below those obtained on the usual standard photometers, but the difference is comparable in magnitude with the uncertainty of the latter values.

TEMPERATURE MEASUREMENTS IN BESSEMER AND OPEN-HEARTH PRACTICE.†

By George K. Burgess.

[ABSTRACT.]

THE problem of temperature measurement and pyrometric control of furnace casting and ingot teeming temperatures is shown, by a series of observations taken in several steel plants, to present no serious difficulties or uncertainties.

* Scientific Paper No. 299.

† Technologic Paper No. 91.

For this purpose the most satisfactory type of instrument is one of the optical pyrometers using monochromatic light and permitting observation from a distance of streams of metal.

It is shown that the necessary corrections to the observed optical pyrometer readings for emissivity of metal and oxides to give true temperatures are sufficiently well known, but there may be uncertainty in the case of liquid slags.

For streams of liquid iron or steel the most probable value of emissivity to take, with a pyrometer using red light of wavelength $\lambda = 0.65\ \mu$, is $e = 0.40$, corresponding to a correction of 139° for an observed temperature of 1500° C. The value of e for liquid slags is usually about 0.65, but varies with composition of the slag. A table of emissivity corrections is included in the text.

Determination of the temperature of the charge of Bessemer converters is not deemed practicable by pyrometric methods.

The operation of the open-hearth furnace can be gauged by the pyrometer, it being possible to control readily the temperature of the roof and of the bath of metal and slag by observations taken through ports; and the temperature of the metal may be had at any instant, with a fair degree of exactness, by observation with the optical pyrometer of metal removed in a spoon.

The temperatures of the roof of an open-hearth furnace are shown to bear no necessary relation to that of the metal bath, which it is again shown may have zones of considerable differences in temperature, depending upon the operation of the furnace.

The temperature of the roof of an open-hearth furnace, dependent upon the firing practice, may vary very rapidly and within wide limits, 1550° to 1750° C. The temperature of the open-hearth bath is usually kept between 1600° and 1670° C.

There appears to be a remarkable degree of uniformity in casting temperature actually acquired by the melters in practice. Thus for nineteen consecutive Bessemer heats the teeming temperatures of the ingots were all between 1500° C. and 1555° C., and a similar degree of concordance, although at slightly higher temperatures, was found in the open-hearth practice of several mills.

It is believed that a continuous, systematic following of the temperature, by the methods above outlined, for the various furnace and casting practices, on the part of steel and iron mills, would show the possibility of improvements and greater certainty

of production in quality of product; also, changes and the effects of variation in ingot or furnace practice could undoubtedly be carried out with greater certainty than at present appears to be the case.

Burning Coal Beds Form Natural Brick. ANON. (*U. S. Geological Survey Press Bulletin. No. 314*, March, 1917.)—Many coal beds in the great coal fields of the western states have at some time taken fire and burned along their outcrops, baking and reddening the overlying strata so that they have become a kind of natural brick or terra-cotta. The fires were in places hot enough to fuse and recrystallize the overlying shale and sandstone so as to form natural slag. At some places this slag resembles true igneous rock; at others it consists largely of rare minerals. Thoroughly fused slag seems to occur chiefly in crevices or chimneys through which the hot gases generated in the burning escaped through the overlying strata to the surface. The chimney-shaped masses of slag are harder than the surrounding baked rock and, after that has weathered away, form the curious pinnacles that surmount many clinker bluffs or buttes in the west.

Some of the coal beds, especially those exposed on the higher hills, were perhaps ignited by lightning; others, according to well-authenticated reports, were ignited by prairie fires or camp fires; but as burning on the outcrop has been so common as to affect most of the coal beds in an area of more than 200,000 square miles, much of it has probably been due to spontaneous combustion.

Coal beds are now burning at or near the surface at many places in the west, where the burning of the bed is disclosed by the smoke and fumes that rise from it and by the heat at the surface of the earth near the outcrop or above the bed—heat so intense that it kills all vegetation. As the coal burns out the overlying rock or earth generally caves in so as to form large fissures in the ground. As the burning works back from the outcrop, the heat acts on the overlying rocks, but finally combustion is smothered for the lack of oxygen. It is difficult to say how far back from the outcrop the burning may extend. Field studies made by the United States Geological Survey, Department of the Interior, indicate that a bed lying beneath 20 feet or less of cover may burn out completely under large areas, and even where the cover is several hundred feet thick the burning may extend 500 feet back from the outcrop.

A brief account by G. S. Rogers of the burning of coal beds in place, with a discussion of the causes and a petrologic and chemical description of some of the baked and fused rock formed, has been published by the United States Geological Survey as Professional Paper 108—A. A copy of this report may be obtained free on application to the Director of the Survey.

NOTES FROM NELA RESEARCH LABORATORY.*

THE EQUALITY-POINT IN SPECTRAL ENERGY AND LUMINOSITY-DISTRIBUTION CURVES OF ILLUMINANTS.

By M. Luckiesh.

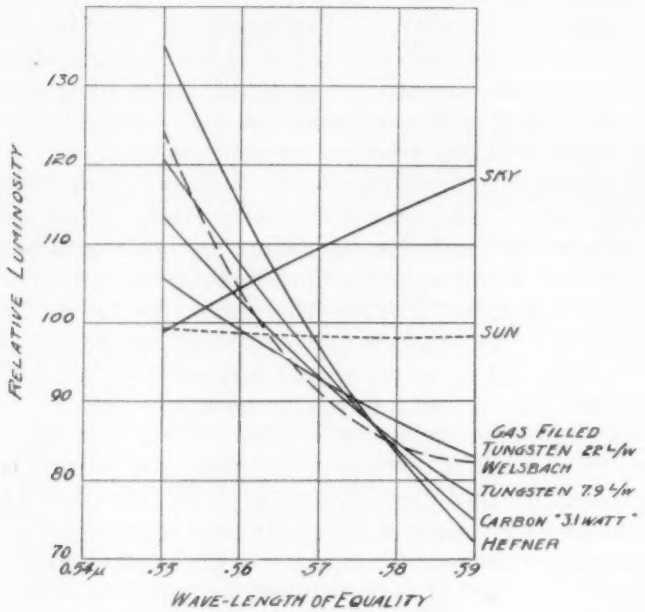
In plotting relative spectral energy-distribution curves of illuminants it is advantageous to choose a wave-length of equality. It is a common procedure to multiply these relative spectral energy-values by the spectral visibility-values to obtain the spectral luminosity-distributions. The latter, when integrated, of course, cannot be directly compared with each other on either the basis of equal luminous efficiency or luminous intensity. It has been of interest to compute the relative luminous intensities in the foregoing manner, using the relative energy-values of the spectral distribution curves made equal at different wave-lengths between 0.57 μ and 0.59 μ and including in these computations noon sunlight and blue skylight. The results are shown in the accompanying illustration. The results are subject to change with any change in the visibility data. For the present purpose Nutting's visibility data (*Trans. I. E. S.*, 1914, **9**, p. 633) have been used.

It is seen that the luminosities are more nearly equal for those common illuminants of extremely different spectral energy-distribution when the equality-point is in the neighborhood of 0.565 μ. This is much nearer the wave-length of maximum visibility than the customary equality-point, 0.59 μ. In the latter case it is seen that there is a wide variation between the resultant relative integral luminosities of blue skylight and the group of artificial illuminants. Incidentally Fig. 1 illustrates that Crova determined fairly closely the wave-length at which photometric measurements would yield results in fair agreement with those made with the integral lights from artificial light-sources in use at that time. His proposed screen transmitted maximally at 0.582 μ. It appears that for most of the common artificial illuminants in use to-day photometric measurements made at a wave-length

* Communicated by the Director.

near 0.575 μ would yield results closely proportional to the integral luminosity-values. For the general case which includes illuminants such as skylight and sunlight, and thus representing the extremes, a wave-length near 0.565 μ appears to be the most desirable point for plotting energy and luminosity-values equal. In the latter case the extreme error would not be more than 10 per cent. in comparing the two illuminants most widely different in spectral character. Even this error might not be too great for some classes of photometry involving the comparison of daylight

FIG. 1.



intensity with an artificial standard of luminous intensity. The advantage of such a screen in eliminating or reducing color-difference in investigating natural lighting is obvious. At any rate, it appears that it would be advisable to adopt 0.565μ as the equality-point in plotting spectrophotometric data and to abandon the use of 0.59 μ. It is interesting to note the results obtained for the radiation from the gas mantle, which departs widely in spectral distribution from that of the black body and many of the common illuminants.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE PHOTOGRAPHIC PRODUCTION OF A LITHOGRAPHIC KEY ON ZINC AND ALUMINUM.[1]

By J. I. Crabtree.

[ABSTRACT.]

In order to facilitate the work of the lithographic artist when drawing in crayon on zinc or aluminum, it is possible to first prepare a photographic image on the metal plate to serve as a key, which may then be worked upon in the usual way. This key may be obtained by an application of the blue-print process to metal, though in order to prevent the final image from washing off the plate it is necessary to pay attention to the following details:

A suitable sheet of grained zinc is first coated with a 1 per cent. solution of citric acid and dried immediately. The following sensitive coating is then applied with a brush and likewise dried immediately:

(A)	Ferric ammonium citrate (Bown scales)..	30 g.	1 oz. 25 gr.
	Water to	150 c.c.	5 oz.
(B)	Potassium ferricyanide	30 g.	1 oz. 25 gr.
	Water to	150 c.c.	5 oz.

For use: 3 parts A; 1 part B.

After exposing under a negative until the shadows are slightly bronzed, the plate should be washed in water, when a blue image results, though a much stronger image may be obtained if the plate is developed in a solution consisting of equal parts of a 1 per cent. solution of potassium ferricyanide and a 1 per cent. solution of citric acid. The high-lights of the zinc may be considerably whitened and the contrast thereby increased by treating the zinc with a weak solution of nitric acid and alum.

A key may be prepared on aluminum in a manner very sim-

* Communicated by the Director.

[1] Communication No. 48 from the Research Laboratory of the Eastman Kodak Company, published in *The National Lithographer* and *British Journal of Photography*.

ilar to the method for obtaining the same on zinc. A suitably grained sheet of aluminum is first coated with a 1 per cent. solution of oxalic acid and dried quickly before a fan. The aluminum is then coated with the ferric ammonium citrate-potassium ferricyanide mixture, as in the case of zinc, and rapidly dried. After exposure, the plate should be developed in plain water, though if a solution consisting of equal parts of 1 per cent. oxalic acid and 1 per cent. potassium ferricyanide is used a bluer and slightly more intense image is obtained.

A COMPENSATING FILTER IN SPECTROSCOPY.*

By M. B. Hodgson and R. B. Wilsey.

[ABSTRACT.]

IT would be desirable in many spectral investigations to have a photographic emulsion which would yield, in the same exposure, equal densities in the developed negative over a wide spectral region when using a light source having a continuous spectrum. Needless to state, while present-day panchromatic dry plates show sensitiveness throughout the whole visible spectrum, and while the modern high-efficiency illuminant is constant in radiant output and more uniform in spectral distribution than heretofore, such an ideal condition does not exist; the sensitiveness of the plate is not a constant value for all wave-lengths, nor is the energy-distribution of the illuminant even approximately uniform.

To overcome these inherent defects, in obtaining quantitative or reliable qualitative measurements of absorption bands, various expedients are employed.

Luckiesh has described a method which he has used with success in obtaining uniform photographic intensity throughout the spectrum, using a light source yielding a continuous spectrum. Morris-Airey suggested this method in 1913.

The spectrum of the light source used is first photographed in the usual manner upon the particular brand of panchromatic plates selected, exposing through the glass, this last in order that re-focusing of the spectrum may be dispensed with in subsequent

* Communication No. 42 of the Research Laboratory of the Eastman Kodak Company, published in the *Journal of the Optical Society*.

exposures. This initial negative is then developed, fixed, dried, and further exposures made, using it as a filter in contact with the emulsion of the print plate, its position coinciding with its original position, thus bringing the screen and print-plate emulsion in approximately the same focal plane. The theory is that those portions of the spectrum which are most actinic will be restrained, in proper ratio, by the densities they have impressed upon the initial plate.

The authors have further investigated this process and determined the photographic constants involved.

Let $I\lambda$ be the intensity of radiation of the wave-length λ, $T\lambda$ the transmission of the compensating filter at that point in the spectrum, and $S\lambda$ the speed or sensitiveness of the photographic emulsion for that particular wave-length. Then

$$I_\lambda T_\lambda S_\lambda = K \tag{1}$$

where K is a constant, is the condition necessary for obtaining equal densities for all wave-lengths upon a photographic plate through the compensating filter.

Density being defined in terms of transmission as follows:

$$\text{Opacity, } O_\lambda = \frac{1}{T_\lambda}$$

$$\text{Density, } D_\lambda = \log O_\lambda = -\log T_\lambda$$

The condition (equation 1) to be fulfilled by the compensating filter may be expressed

$$D_\lambda = \log I_\lambda + \log S_\lambda - \log K \tag{2}$$

$D\lambda$ refers to the compensating filter and $S\lambda$ to the emulsion on which further "prints" are to be made; the value of K is arbitrary, depending on the density produced in the print plate. It is only required that K be constant for all wave-lengths.

Gun Versus Armor. J. B. WALKER. (*Scientific American*, vol. cxvi, No. 14, p. 346, April 7, 1917.)—The excessive ranges at which naval engagements have been fought have been among the surprises of the present war. For several years prior to 1914 target practice was carried on in our own navy at ranges of

9000 to 10,000 yards, and, so far as we know, 10,000 yards was accepted by the foreign navies as the maximum at which it was necessary to train the gun crews for the actual ordeal of battle. Early in the war, however, it was realized that fighting was going to be done at the maximum ranges at which the ship having the speed-gauge could land effectively on the enemy, and engagements have taken place at 12,000, 15,000, and 20,000 yards. With the continually increasing calibres of naval guns, and pieces as large as 18 and 20 inches calibre contemplated, it is quite conceivable that future engagements will be fought at ranges varying between 20,000 and 25,000 yards according to conditions of visibility.

The armor plan of most existing battleships is drawn up to meet conditions of attack at ranges of 8000 to 10,000 yards. The vitals of the ships are protected by a heavy water-line belt associated with a protective deck about three inches in thickness. In some of the later ships there are two protective decks, one in the usual position just above the water-line and the other at the gun deck at the level of the top of the belt. The ammunition hoists and the barbette and turret mechanism are protected by thick vertical armor, and the turret by a heavy sloping port-plate associated with lighter armor on the side walls and at the rear, and light armor 3 to 5 inches in thickness on the roof. The present method of distributing the armor was designed to meet the conditions of 10,000-yard ranges where the angle of impact of the projectile is about 6 degrees with the horizontal. With an impact angle of 22 degrees resulting from ranges greater than 20,000 yards, it is a question whether our present methods of armor distribution should not be altered to meet the new conditions.

Taking it for granted that the vitals of the ship should have the first call upon the armor, it would seem that efforts should be directed to bursting the high-explosive shells as far above the protective deck as possible, on the probability that where an unexploded shell might go through, its fragments would not. It becomes a pertinent consideration, then, whether it is not better to distribute the heavy belt in the form of lighter armor extending over the whole side of the ship, retaining the 2-inch armor of the protective deck, and armor the upper deck in preference to the gun deck. The complete armoring of the above-water portion of the ship would go far to insure the bursting of the shells as soon as they entered. The probability is that the shock of penetrating this outer armor would cause the shell to burst above the main deck, and in any case there would be the additional shock of passing through the main and gun decks to cause fragmentation before the protective deck was reached.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, April 18, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 13.

Mr. William C. Wetherill, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

Charles Baskerville, Esq., Ph.D., Director of Chemical Laboratories, College of the City of New York, presented a communication on the "Hydrogenation of Oils." The various saturated, unsaturated, and hydroxy acids, which occur in animal and vegetable fats and oils, were described by means of charts. The mixed glycerides of such fats and oils were discussed, together with the successive changes produced in their unsaturated radicals by hydrogenation. Attention was paid to the rôle of catalysis in hydrogenation, and to the factors which may favor or retard the reaction in its commercial application. Stress was laid on the economic importance of hydrogenated oils, and the relationship of such oils to the natural fats.

The subject was illustrated by experiments and lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1916–1917.

COURSES OF INSTRUCTION.

The ninety-third year of The Franklin Institute School of Mechanic Arts closed April 13th, 1917. During the year instruction was given in Mechanical Drawing, Architectural Drawing and Design, Freehand Drawing and Water Color, Shop Arithmetic and Algebra, Plane Geometry and Trigonometry, Applied Mechanics and Machine Design, and Theoretical and Practical Naval Architecture.

The courses in Mechanics and Naval Architecture were extended and instruction was given three evenings a week instead of two as in the past.

REGISTRATION.

The total registration for the year was three hundred and seventy-two, an increase of 21 per cent. over that of last year. Large classes were enrolled in First Year Mathematics and in First Year Mechanical Drawing. A marked interest was shown in the course in Naval Architecture.

ATTENDANCE AND PROGRESS.

Because of the unprecedented activity in the industrial plants many of the students were unable to attend classes regularly. However, during the first term thirty-eight students had a perfect attendance record and forty-eight had a perfect attendance record during the second term. In the regular school work forty-one students made an average of 90 per cent. or over during the first term, and thirty-five an average of 90 per cent. or over during the second term.

The high grade of work done by the students in all classes and the large enrollment indicate that the school has completed one of the most satisfactory years in its history.

FACULTY.

In order to give more personal attention to each student the Committee on Instruction decided to limit the size of each class to approximately twenty-five. This plan made it necessary to increase the number of instructors, and the following gentlemen were appointed:

Dr. Ross W. Marriott, of Swarthmore College Faculty, Mathematics.

Mr. Wm. F. Turnbull, of the University of Pennsylvania Faculty, Mechanical Drawing.

Mr. Arthur J. Stretton, Baldwin Locomotive Works, Mechanical Drawing.

Mr. Joseph W. Thompson, New York Shipbuilding Company, Naval Architecture.

Mr. C. J. Walton, Engineering Department, Bell Telephone Company, Mathematics.

Mr. Howard S. Eitzel, Phillips Brooks School, Mathematics.

Mr. Joseph L. Mounce, of the University of Pennsylvania Faculty, was appointed to continue the work of Mr. Frank H. Lobb, in Mechanical Drawing, who resigned on November 9, 1916.

SCHOLARSHIPS.

Eighteen scholarships were available for students of the School; five of these were Bartol Scholarships in Drawing, derived from the B. H. Bartol Fund; thirteen scholarships were derived from the Isaac B. Thorn Fund, and were awarded to students in Mathematics, Mechanics and Naval Architecture.

PRIZES.

Valuable prizes were offered by the following gentlemen for meritorious work in the various departments:

Mr. Samuel M. Vauclain, Vice-President, The Baldwin Locomotive Works.

Mr. J. B. McCall, President, Philadelphia Electric Company.

Mr. Wilfred Lewis, President, Tabor Manufacturing Company.

Mr. J. T. Wickersham, Secretary and Treasurer, The New York Shipbuilding Company.

Mr. Robert W. Lesley, Past-President, Portland Cement Association and Member of the Board of Managers of The Franklin Institute.

The Alumni Association continued its special prizes to the graduates having the best records and to graduates having a perfect attendance for the year.

HONORS.

Certificates for the satisfactory completion of a course in one of the Departments of Drawing, Mathematics, Mechanics or Naval Architecture are this year awarded to forty-one students. Appended are the names of these graduates, also the names of those students to whom are awarded the scholarships and prizes indicated above, and the names of those students granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

The success of the year that has just closed may be attributed to the hearty coöperation of officials of the various manufacturing plants, to the earnest and the continued application of the students, and to the conscientious work done by the members of the Faculty.

Respectfully submitted,

SIMEON VAN T. JESTER,
Director.

April 20, 1917.

LIST OF GRADUATES, ETC., 1916–17.

CERTIFICATES.

CERTIFICATES ON THE SATISFACTORY COMPLETION OF FULL COURSES ARE AWARDED AS FOLLOWS:

MECHANICAL DRAWING.

Lloyd B. Avis.
W. C. Callingham
Dirk A. Dedel
Ludwig Frank
Oscar Goertz
John Hysore
George Jahke
Jay C. Lafferty, Jr.
Robert Morris
John MacConnell
H. J. Schmid

ARCHITECTURAL DRAWING.

Leon Chatelain, Jr.
N. A. Hansen
Ferdinand A. Noll
Everett B. Powers
Albert Witt

FREEHAND DRAWING AND WATER COLOR.

Christian P. Kopp

MATHEMATICS.

Branson Barnes
John R. Blowe
Joseph A. Chamberlain
Edward S. DeHart
Harry Haering
Clarence H. Jaggers
Harry Kretzschmar
E. Branson Parker
Aden W. Powell
Robert J. Roesch
Frank Rorer, Jr.
W. C. Schmoll
Carl W. Slemmer
Rudolph K. Wood

MECHANICS.

Benjamin A. Beavan
John F. Casey
George D. Collar, Jr.
Raymond J. Davis
Jacob H. Finkelstein
Joseph G. Floody
Abraham Perlman
W. Frank Titus

NAVAL ARCHITECTURE.

Thomas I. Cooper
Carl Schultz

BARTOL SCHOLARSHIPS.

DEPARTMENT OF DRAWING.

George W. Hardman
Architectural
Russell Morehouse
Mechanical
Jessie J. Moyer
Architectural
Wilson D. Scott
Mechanical
D. P. Smith
Mechanical

THORN SCHOLARSHIPS.

DEPARTMENT OF MATHEMATICS.

Frank Baker
Joseph Chamberlain
Edward S. DeHart
Randall Ellis
Thomas C. Gatley
Andrew Hetherington
Robert Hetherington
William Kuenstle
John Schaad
Rudolph K. Wood

DEPARTMENT OF NAVAL ARCHITECTURE.

Roscoe Bateman
Theodore G. Grier
John L. Starr

MR. S. M. VAUCLAIN'S PRIZE.

MECHANICS.

John F. Casey

MR. WILFRED LEWIS' PRIZE.

MECHANICS.

Joseph G. Floody

MR. J. B. McCALL'S PRIZE.

MATHEMATICS.

Aden W. Powell

MR. ROBERT W. LESLEY'S PRIZE.

DRAWING.

John MacConnell

NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Thomas I. Cooper

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE'S PRIZES.

Aden W. Powell
Mathematics

John F. Casey
Mechanics

Carl Schultz
Naval Architecture

Ferdinand A. Noll
Architectural Drawing

John MacConnell
Mechanical Drawing

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 4, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 4, 1917.

Mr. WM. CHATTIN WETHERILL *in the Chair.*

The following reports were presented for first reading:

No. 2683.—Yeoman's Method of Machine Construction.

No. 2687.—Portable Brinell Meter.

The following report was presented for final action:

No. 2688.—Becker's Chainomatic Balance.

Edward Longstreth Medal of Merit to Christopher A. Becker, of New York City, N. Y.

On the recommendation of the Sub-committee on Literature, the following awards were made for papers in the JOURNAL, 1916:

No. 2696.—The Howard N. Potts Medal to Prof. Ulric Dahlgren, of Princeton, N. J., for his paper, entitled "The Production of Light by Animals," described by the Sub-committee as forming an original and comprehensive treatise of an extremely interesting and important subject.

No. 2697.—The Edward Longstreth Medal of Merit to Mr. George A. Rankin, of Washington, D. C., for his paper, entitled "Portland Cement," described by the Sub-committee as a highly important contribution to the theory of cement chemistry.

No. 2698.—The Edward Longstreth Medal of Merit to Prof. A. E. Kennelly, of Cambridge, Mass., for his paper, entitled "Experimental Researches on the Skin Effect in Steel Rails," described by the Sub-committee as containing new and valuable experimental data, heretofore unavailable to the designers of track return systems.

No. 2699.—The Edward Longstreth Medal of Merit to Mr. John D. Ball, of Schenectady, N. Y., for his paper, entitled "Investigation of Magnetic Laws for Steel and Other Material," described by the Sub-committee as containing new and valuable information relating to the magnetic properties of materials used in the magnetic circuits of electrical machinery.

No. 2700.—The Edward Longstreth Medal of Merit to Prof. Dayton C. Miller, of Cleveland, Ohio, for his papers, entitled "A 32-Element Harmonic Synthesizer," and the "Henrici Harmonic Analyzer and Devices for Extending and Facilitating its Use," described by the Sub-committee as a comprehensive and lucid discussion of harmonic synthesis and analysis, together with descriptions of perfected apparatus for synthesizing and analyzing functions of one variable expressible by Fourier's equation.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 29, 1917, at 8 o'clock, with Dr. Gellert Alleman in the chair. The meeting was held in conjunction with the Philadelphia Section of the American Chemical Society. The minutes of the previous meeting were read and approved.

H. S. Mork, B.S., of Arthur D. Little, Incorporated, Boston, Mass., delivered an address on "The Chemistry of Cellulose and its Important Industrial Applications." The chemical composition of cellulose was discussed and its reactions were described, especially those reactions which form the basis of the manufacture of viscose, cellulose nitrates, cellulose acetates, cellulose ethers, and artificial silk. The properties of these products and their applications in the arts were outlined. The lecture was illustrated with specimens. After a discussion of the paper, a vote of thanks was extended to Mr. Mork and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 5, 1917, at 8 o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

Wilder D. Bancroft, Ph.D., Professor of Physical Chemistry in Cornell University, presented a communication on "Contact Catalysis," in which the theory of that phenomenon and its applications in inorganic, organic, biological, and industrial chemistry were discussed at length.

On motion of Mr. Louis E. Levy, a vote of thanks was extended to Dr. Bancroft, and he was requested to submit his paper for publication in the JOURNAL OF THE INSTITUTE. The paper was discussed and the meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 12, at 8 o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were approved as read.

William Albert Noyes, Ph.D., LL.D., Director of the Chemical Laboratory of the University of Illinois, and editor of the *Journal of the American Chemical Society*, delivered an address on "The Electron Theory." The developments in the knowledge of matter and energy, and of their relation to each other, were traced, from the time of the discovery of oxygen to the present. An account was given of the discovery of electrons or atoms of negative electricity. The nature of the attractions between atoms, which cause them to unite to form compounds, was discussed. The lecture was illustrated with lantern slides and experiments.

The paper was discussed by Doctors Brush, Morley, Hoadley, Cope, Kershner, and others. A vote of thanks was extended to Doctor Noyes, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(*Stated Meeting Board of Managers, April 11, 1917.*)

RESIDENT.

DR. BERTHA MAY CLARK, Head of Science Department, William Penn High School, and for mail, 1904 Green Street, Philadelphia, Pa.

MR. WAYNE S. EVANS, S. W. Evans & Son, 4623 Paul Street, Frankford, Philadelphia, Pa.

MR. JONATHAN JONES, Civil Engineer, 530 City Hall, Philadelphia, Pa.

MR. HENRY W. LEBOUTILLIER, Chemist, Wayne, Pa.

NON-RESIDENT.

MR. G. W. CREIGHTON, General Superintendent, Eastern Pennsylvania Division, Pennsylvania Railroad Company, Altoona, Pa.

MR. E. M. FITZ, Electrical Engineer, Motive Power Department, Pennsylvania Lines West of Pittsburgh, Columbus, Ohio.

DR. MILTON W. FRANKLIN, Research Engineer, E. F. Houghton & Company, 240 West Somerset Street, Philadelphia, Pa.

MR. R. E. GLOVER, Chemist, Experimental Station, E. I. du Pont de Nemours Company, and for mail, 1411 Jackson Street, Wilmington, Del.

MR. HERMAN LIVINGSTON, Hydro-Carbon Engineer, Ætna Explosives and Ætna Chemical Companies, P. O. Box 543, Carnegie, Pa.

MR. PERCY MCGEORGE, Prætorian Building, Dallas, Texas.

MR. J. J. RHOADS, Sperintendent, Schuylkill Division, Pennsylvania Railroad Company, and for mail, 957 Centre Avenue, Reading, Pa.

MR. N. W. SMITH, Superintendent, Middle Division, Pennsylvania Railroad Company, Altoona, Pa.

MR. ETHAN VIALL, Western Editor, *American Machinist*, 3556 Montieth Avenue, Hyde Park, Cincinnati, Ohio.

CHANGES OF ADDRESS.

MR. W. H. CRAGO, Room 3623, 120 Broadway, New York City, N. Y.

PROF. W. S. FRANKLIN, Washington, Conn.

MR. J. ROGERS HOLCOMB, Wilmington Steel Company, Wilmington, Del.

MR. MORRIS KNOWLES, 1200 B. F. Jones Law Building, Fourth Avenue and Ross Street, Pittsburgh, Pa.

MR. MARSHALL MILLER, 911 North Eighth Street, Philadelphia, Pa.

MR. W. S. RUGG, Pittsburgh Athletic Club, Fifth Avenue, Pittsburgh, Pa.

MR. JOHN P. B. SINKLER, 412 Otis Building, 112 South Sixteenth Street, Philadelphia, Pa.

NECROLOGY.

Dr. Arthur Beardsley was born at Esopus, N. Y., November 1, 1843, and died at Swarthmore, Pa., on January 29, 1917.

He studied at Bowdoin College and afterward at the Rensselaer Polytechnic Institute, at Troy, N. Y., from which institution he was graduated in 1867 with the degree of Civil Engineer.

The year following his graduation was spent as an assistant engineer in the construction of the Hoosac Tunnel, and the following year as a civil engineer and architect in Poughkeepsie, N. Y.

He then became instructor of civil engineering and industrial mechanics at the University of Minnesota, and for the two following years, 1870–'72, professor of these subjects in the University.

In 1872 he became professor of applied mathematics and engineering in Swarthmore College, which position he retained until 1898, when he was compelled to resign on account of impaired vision and was made emeritus professor of engineering.

He was a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, and a fellow of the American Association for the Advancement of Science.

He was elected a member of The Franklin Institute on April 8, 1874, and a member of the Board of Managers in June, 1894.

He served for eight years on the Committee on Science and the Arts, and was chairman of this committee in 1892.

Besides being a practical engineer of acknowledged ability, Dr. Beardsley had the qualities which rendered him a highly efficient teacher in training young men for the engineering profession.

He put the same energy and interest into his participation in the activities of the Institute, and when, in 1901, his failing eyesight rendered further service impossible, the Board of Managers expressed appreciation of his services by electing him to Honorary Membership.

G. A. H.

Richard Waln Meirs was born in Waterford, N. J., in 1866, and died in Philadelphia, April 21, 1917. Mr. Meirs was educated at the Eastburn Academy, Philadelphia, and the Freehold Institute at Freehold, N. J. He then entered Princeton University and was graduated in the class of 1888. He occupied a distinguished position in financial circles, both in Philadelphia and New York. Along with his other activities, in 1905, Mr. Meirs became manager of the Weightman-Walker estates, in which capacity he continued until his death. His interest in the liberal arts is attested by his membership in many societies.

He became a member of The Franklin Institute in 1905, and was a member of its Board of Managers since 1908.

Mr. J. J. Burleigh, Merchantville, N. J.

LIBRARY NOTES.

PURCHASES.

British Journal Photographic Almanac. 1916.

BUSHNELL, S. M., and ORR, F. B.—District Heating. 1915.

CLARK, V. S.—History of Manufactures in the United States, 1607–1860.

DUCHENE, CAPTAIN.—The Mechanics of the Aeroplane. 1915.

FINDLAY, ALEX.—Chemistry in the Service of Man. 1916.

HAMILTON, D. T., and JONES, F. D.—Advanced Grinding Practice. 1915.

HOLMS, A. C.—Practical Ship Building. 2 vols. 1916.

International Catalogue of Scientific Literature, No. 12. H—Geology. 1916.

JOHNSON, J. E., JR.—Blast-furnace Construction in America. 1917.

LYON, T. L., FIPPIN, E. O., and BUCKMAN, H. O.—Soils: Their Properties and Management. 1916.

MURRAY, A. J.—The Strength of Ships. 1916.

PERRIN, JEAN.—Atoms. (Translation from the French by D. L. Hammick.) 1916.

Reader's Guide to Periodical Literature, Supplement No. 4. 1916.

ROE, J. W.—English and American Tool Builders. 1916.

WEST, GEORGE.—Practical Principles of Plain Photo-micrography. 1916.

GIFTS.

Alabama Geological Survey, Bulletin No. 18, Preliminary Report on the Crystalline and Other Marbles of Alabama, by William F. Prouty. University, 1916. (From the Survey.)

Alpha Portland Cement Company, Alpha Cement and How to Use It. Easton, Pa., 1917. (From the Company.)

Aluminum Company of America, Aluminum Electrical Conductors. Pittsburgh, no date. (From the Company.)

American Electric Railway Engineering Association, Proceedings, 1916. New York, 1916. (From the Association.)

American Ephemeris and Nautical Almanac for the Year 1919. Washington, 1917. (From the Nautical Almanac Office.)

American Institute of Mining Engineers, Transactions, vol. liv, 1916. New York, 1917. (From the Institute.)

American Sheet and Tin Plate Company, Black Sheets and Special Sheets, and Research on the Corrosion Resistance of Copper Steel. Pittsburgh, 1916. (From the Company.)

American Society of Civil Engineers, Year Book, February, 1917. New York City, 1917. (From the Society.)

Argentina Comision Protectora de Bibliotecas Populares, Annales de la Biblioteca, Tomo x. Buenos Aires, 1915. (From the Commission.)

Brown Instrument Company, Catalogue of Brown Instruments for Measuring Temperature, Pressure, Electricity, and Speed. Philadelphia, no date. (From the Company.)

Bruce, Robert, The National Road, Baltimore and Washington to Wheeling, West Va. Clinton, Oneida County, N. Y. 1916. (From the Author.)

Bureau for the Safe Transportation of Explosives and Other Dangerous Articles. Report of the Chief Inspector, February, 1917. New York, 1917. (From Col. B. W. Dunn.)

Canada Department of Mines, Geological Survey, Memoir 88, Geology of Graham Island, British Columbia, and Memoir 94, Ymir Mining Camp, British Columbia. Ottawa, 1916–1917. (From the Department.)

Canadian Society of Civil Engineers, Transactions, vol. xxix, part ii, October to December, 1915. Montreal, 1916. (From the Society.)

Cheney Brothers, The Miracle Workers, The Story of Silk, and A Short Description of Silk and Silk Manufacture. South Manchester, Conn., 1916. (From the Company.)

Commercial Camera Company, The Photostat Book. Rochester, N. Y., no date. (From the Company.)

Delaware College, Annual Catalogue, 1916–1917. Newark, Del., 1917. (From the College.)

Dunham (C. A.) Company, Bulletins of Heating and Ventilating Specialties. Marshalltown, Iowa, 1913–1916. (From the Company.)

Edison Lamps Works of the General Electric Company, A Handbook on Incandescent Lamp Illumination. Harrison, N. J., 1916. (From the Company.)

Fellows Gear Shaper Company, Commercial Gear Cutting, The Gear Shaper Cutter, The Helical Gear Shaper, The Involute Gear, and The Stub-tooth Gear. Springfield, Vt., 1909–1916. (From the Company.)

Foster Machine Company, The Foster No. 1 B Universal Turret Lathe with Tools and Attachments. Elkhart, Ind., no date. (From the Company.)

General Education Board, Report of the Secretary, 1915–1916. New York City, 1916. (From the Board.)

General Fireproofing Company, The Fireproofing Hand-Book, Fifth Edition, 1916. Youngstown, 1916. (From the Company.)

Great Britain Board of Trade, Boiler Explosions Act, 1882, Thirty-third Annual Report upon the Working of the Act. London, 1916. (From the Manchester Steam Users' Association.)

Haldane, John Scott, Organism and Environment as Illustrated by the Physiology of Breathing. New Haven, 1917. (From Yale University.)

Hobart College Catalogue, 1916–1917. Geneva, N. Y., 1917. (From the College.)

Indiana Department of Geology and Natural Resources, Fortieth Annual Report, 1915. Indianapolis, 1916. (From the Department.)

Institute of Metals, Journal, vol. xvi, No. 2, 1916. London, 1916. (From the Institute.)

International Clay Products Bureau, The Clay Pipe Book. Kansas City, Mo., 1917. (From the Bureau.)

Iron and Steel Institute, Journal, vol. xciv, No. 11. London, 1916. (From the Institute.)

John Crerar Library, A List of Books on the History of Science, Supplement, December, 1916. Chicago, 1917. (From the Library.)

Leland Stanford Junior University Library, List of Serials. Stanford University, Calif., 1916. (From the Library.)

Lyman, Benjamin Smith, Vegetarian Diet and Dishes. Philadelphia, 1917. (From the Author.)

Massachusetts Institute of Technology, President's Report, 1917. Cambridge, 1917. (From the Institute.)

Mississippi State Geological Survey, Bulletin No. 13, Marls and Limestone of Mississippi, by William N. Logan. Jackson, 1916. (From the Survey.)

Municipal School of Technology, Journal, vol. viii. Manchester, 1914. (From the School.)

Murphy Iron Works, Catalogue No. 25, The Murphy Automatic Smokeless Furnace. Detroit, 1912. (From the Works.)

Music Trades Company, The Piano and Organ Purchaser's Guide for 1917, Twenty-first Annual Edition. New York, 1917. (From the Company.)

Mysore Government, Meteorological Department, Report on Rainfall Registration in Mysore, 1915. Bangalore, 1916. (From the Department.)

New York Public Library, Handbook. New York, 1916. (From the Library.)

New York State Library, Ninety-eighth Annual Report, 1915. Albany, 1917. (From the Library.)

New Zealand Government Statistician, Statistics of the Dominion, 1915, vol. i, Blue Book, Population and Vital Statistics, Law and Crime. Wellington, 1916. (From the Government Statistician.)

Northrup, Edwin F., Laws of Physical Science. Philadelphia, 1917. (From the Author.)

Oberlin College, The Annual Catalogue, 1916–1917. Oberlin, Ohio, 1917. (From the College.)

Ohio Brass Company, Steam Road Electrifications. Mansfield, 1917. (From the Company.)

Ontario Bureau of Mines, Twenty-fifth Annual Report, 1916, vol. xxv, part iii, The Geology of Kingston and Vicinity, by M. B. Baker. Toronto, 1916. (From the Bureau.)

Pennsylvania Commission to Investigate the Increase in the Cost of Anthracite Coal, Report, 1915. Harrisburg, no date. (From the State Librarian.)

Pennsylvania Department of Forestry, Report for the Years 1914–1915. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Superintendent of Public Instruction, Report for the Year Ending July 3, 1916. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Superintendent of Public Printing and Binding, Annual Report for the Year Ending June 30, 1915. Harrisburg, 1916. (From the State Librarian.)

Philadelphia City Councils, Manual, 1917. Philadelphia, 1917. (From the Chief Clerk, Select Council.)

Philadelphia College of Physicians, Transactions, Third Series, vol. 38. Philadelphia, 1916. (From the College.)

Pike Manufacturing Company, Sharpening Stones, History and Development. Pike, N. H., 1915. (From the Company.)

Powell (William) Company, Catalogue No. 10, Third Edition, Dependable Engineering Specialties. Cincinnati, 1916. (From the Company.)

Robbins & Myers Company, Bulletins Nos. 105, 107, 109, 111, 113, 115, 121, 123, 125, 127, and 129, descriptive of Motors and Generators. Springfield, Ohio, 1915–1917. (From the Company.)

South Australia Government Geologist, Annual Report, 1915. Adelaide, 1916. (From the Government Geologist.)

Springfield (Mass.) Water Commissioners, Forty-third Annual Report, 1916. Springfield, 1917. (From the Commissioners.)

Syracuse University, Catalogue, 1916–1917. Syracuse, N. Y., 1917. (From the University.)

Toledo Pipe Threading Machine Company, Toledo Pipe Threading Hand Book. Toledo, Ohio, no date. (From the Company.)

United Engineering and Foundry Company, Bulletins A, B, F, I, M, P, R, and S1. Pittsburgh, 1916–1917. (From the Company.)

United Motors Corporation, Prospectus. New York, no date. (From the Corporation.)

U. S. Naval Academy Graduates' Association, Register of Graduates, June, 1916. Annapolis, Md., 1916. (From the Association.)

Westinghouse Lamp Company, The Lighting Dictionary, Salesmen's Lamp Handbook Series No. 2. New York, no date. (From the Company.)

White Fuel Oil Engineering Corporation, The White Low-pressure Mechanical Oil-burning System, and Instructions for Running the System. New York, 1916. (From the Corporation.)

Williams Tool Company, Catalogue of Tools. Erie, Pa., no date. (From the Company.)

Witte Engine Works, Catalogue No. 47, How to Judge Engines. Kansas City, Mo., 1916. (From the Works.)

BOOK NOTICES.

THE INTERNATIONAL MILITARY DIGEST ANNUAL for 1916. Col. C. De W. Willcox and Lieut.-Col. E. R. Stuart, Editors-in-Chief, with the coöperation of 31 Associate Editors. New York, Cumulative Digest Corporation, 1917. 630 pages, 8vo. Price, $5.

The International Military Digest is a monthly periodical containing abstracts of articles of military interest appearing in current literature published at home and abroad. The present volume is the cumulation of the monthly issues for the year 1916. The abstracts, with which are given the title of periodical, author, date, and number of words, give a very satisfactory *résumé* of the original articles. Obviously at this time, when the entire civilized world is either at war or preparing for war, a condensed account of current military activities is of rare interest alike to layman and expert. The work is not merely a collection of the monthly issues of the *Digest;* the articles are rearranged in classified alphabetical order, with many cross-references, an arrangement which materially adds to its value.

LUCIEN E. PICOLET.

GAS CHEMISTS' HANDBOOK. Compiled by Technical Committee, Sub-Committee on Chemical Tests: C. C. Tutwiler, Chairman; A. F. Kunberger, Editor. New York: American Gas Institute, 1916. 345 pages, contents and index, illustrations, 8vo. Price, $3.50.

This is a collection of analytic procedures for use by gas chemists, with some accessory matters, such as tests of construction materials, alloys, and lubricating oils. Many of the methods are in tentative form, as the committee has not yet been able to determine their value absolutely, but the procedures for coal, coke, cement, iron, and steel are regarded as substantially established. The work is well printed, liberally illustrated, and correct chemical terms are mostly used. The reviewer regrets to note, however, such absurd terms as "benzol" and "nitrobenzol." Surely the chemists who are engaged in American laboratories know enough chemical nomenclature not to be confused by the title "benzene," and there is no excuse for retaining a highly erroneous term.

The reviewer notes two typographic errors: on page 171, "Effervescent" should, it seems, be "efflorescent" and on page 175 the formula for sodium picrate is wrong.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. War Department: Annual Reports, 1916: Vol. 1, Secretary of War, Chief of Staff, The Adjutant-General, Inspector General, Judge-Advocate General, Quartermaster-General, Surgeon-General, Chief of Ordnance, Chief Signal Officer, Chief of Militia Bureau, Chief of Coast Artillery, Military Academy, Military Parks; Vol. 2, Chief of Engineers; Vol. 3, Chief, Bureau of Insular Affairs, Governor of Porto Rico, Philippine Commission. 3 volumes, plates, maps, diagrams, tables, 8vo. Washington, Government Printing Office, 1916.

Preliminary Mathematics, by Prof. F. E. Austin, B.S., E.E. 169 pages, 12mo. Hanover, N. H., Author, 1917. Price, $1.20.

Manila Bureau of Science, Division of Mines: The Mineral Resources of the Philippine Islands for the Year 1915. 39 pages, map. 8vo. Manila, Bureau of Printing, 1916.

Ontario Bureau of Mines: Twenty-fifth Annual Report, 1916. The Geology of Kingston and Vicinity, by M. B. Baker. 71 pages, 8vo. Toronto, King's Printer, 1916.

University of Illinois: A Brief Prepared for the Governor and the General Assembly of the State of Illinois Concerning the Work of the College of Engineering and the Engineering Experiment Station of the University of Illinois and a Statement of Their Needs for the Two Years Beginning July 1, 1917. 28 pages, illustrations, plates, quarto. Urbana, 1917.

U. S. Bureau of Mines: Bulletin 119, Analyses of Coals Purchased by the Government During the Fiscal Years 1908–1915, by George S. Pope. 118 pages. Technical Paper 82, Oxygen Mine Rescue Apparatus and Physiological Effects on Users, by Yandell Henderson and James W Paul. 102 pages, illustrations, plates. Technical Paper 137, Combustion in the Fuel Bed of Hand-

fired Furnaces, by Henry Kreisinger, F. K. Ovitz, and C. E. Augustine. 76 pages, illustrations, diagrams, plates. Monthly Statement of Coal-mine Fatalities in the United States, January, 1917; List of Permissible Explosives, Lamps, and Motors Tested Prior to February 28, 1917, Compiled by Albert H. Fay. 4 Pamphlets, 8vo. Washington, Government Printing Office, 1916–1917.

American Telephone and Telegraph Company: Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1916. 64 pages, 8vo. New York, 1917.

Canada Department of Mines, Mines Branch: Production of Coal and Coke in Canada During the Calendar Year, 1915. 42 pages. Production of Cement, Lime, Clay Products, Stone, and Other Structural Materials in Canada During the Calendar Year 1915. 60 pages. Production of Copper, Gold, Lead, Nickel, Silver, Zinc and Other Metals in Canada During the Calendar Year 1915. 82 pages. Preliminary Report of the Mineral Production of Canada During the Calendar Year 1916. 25 pages. 4 pamphlets, 8vo. Ottawa, Government Printing Bureau, 1916–1917.

U. S. Department of Agriculture: Bulletin 463, Earth, Sand-clay, and Gravel Roads, by Charles H. Moorefield, Senior Highway Engineer. 68 pages, illustrations, plates. 8vo. Washington, Government Printing Office, 1917.

Spray Engineering Company: Spraco Products, Spray Cooling Equipment, Air Washing and Cooling Equipment, Paint Spraying Equipment, Park Sprinklers, Flow Meters, Nozzles for All Purposes. 15 pages, illustrations, quarto. Boston, Company, 1917.

A Clock of Precision. C. O. BARTRUM. (*Proceedings of the Physical Society of London*, vol. xxix, pt. ii, p. 120, February 15, 1917.)—In designing a pendulum clock, provision has to be made for automatically counting the swings and for maintaining the arc of the pendulum. In general practice, these are effected by some form of release, actuated by the pendulum itself, or of contact with the pendulum whereby the vibrations are recorded and the signal given to the motive mechanism that the pendulum is in the position to receive its impulse. Such methods are objectionable so far as the disturbance thereby caused to the free swing of the pendulum is constant. In practice this is impossible.

The principal feature of the author's arrangement is the employment of a "slave" clock to do the great part of the work, leaving the master pendulum no function beyond that of controlling the rate of the other. The master pendulum swings freely except for a short period (about one-fifth of a second) every minute, during which it receives an impulse from a small falling wheel electromagnetically released by the slave clock. At the end of its fall the impulse mechanism closes a second circuit and is restored to its initial position. These two electric circuits also energize parts of the mechanism in the slave clock by which the latter is kept in time with the master pendulum. The lagging of correction behind error, with the resulting periodic fluctuation in the rate, is reduced almost to the vanishing point by the introduction of a "negative backlash" in the control mechanism.

CURRENT TOPICS

Steels Suited to Aeronautical Purposes. G. A. RICHARDSON. ("Proceedings of the Aeronautical Society of America," *Iron Age*, vol. 99, No. 13, p. 778, March 29, 1917.)—In considering steels available for aeronautical purposes, the subject logically divides itself according to the requirements of structural parts and members, as follows: Stay wires, struts, body parts, etc., power plants and transmission parts, protective armor for military planes, aeronautical instruments, and miscellaneous equipment.

Much attention has been given to the results of tests on the best forms of terminal connections as having bearing on the quality of stay wire that can be satisfactorily used. The original object in using wires for stays was to make it as strong as possible so as to reduce weight. This resulted in a wire so hard and strong that difficulty was experienced in forming the eye and bend for the terminal connection without breaking the wire. The final results of tests to date are that the best wire to use is that which is sufficiently strong and serviceable to permit some reduction in weight, but which combines high tensile strength, toughness, and ductility as well. Carefully-made, high-grade carbon steel affords to-day the most reliable and flexible material for the purpose. Protection against corrosion is of the greatest importance; galvanizing and tinning should always be used in conjunction with a protective coating of paint and not by themselves. Struts should also be designed for minimum weight with maximum strength. This end is best secured by the adoption of cold-drawn chrome-nickel-steels. A protective coating is essential with these members also.

For the engine it is desirable to use steels that do not corrode easily, and for such parts as cylinders that will not be injured by overheating, a condition especially possible in the event of a cooling plant giving out. Professor Lucke, of Columbia University, recommends the use of ordinary, comparatively low carbon steel, cold drawn to shape. By this method of manufacture, a cylinder of uniform wall thickness can be obtained of satisfactory thermal conductivity and possessing at the same time the requisite toughness to enable it to wear well. He objects to the use of alloy compositions, on the ground that they will be injured by overheating and that ordinary steel answers all purposes. Twenty-five per cent. nickel steel is not open to this objection. It is also quite resistant to corrosion and is non-magnetic. Piston and connecting rods can follow automobile practice. Crankshafts and camshafts may be made of chrome-nickel-steel, the latter case-

hardened. For valve parts, three per cent. nickel-steel, because of its resistance to corrosion, low coefficient of expansion, and other physical properties, is recommended. Cams and tappets have been made of special alloys, but carbon steel also gives good results. Unquestionably there are important advantages to be gained by the use of metal propellers, and, as a solid section seems desirable, it seems quite certain that some light-weight alloy will prove superior to steel.

The design in the power and transmission plants should be made first, and then, if necessary, the elastic limit increased by the use of chrome-nickel-steel. On short flights the engine and transmission parts weights are of more importance than the amount of lubricating oil, while on long flights the increase in weight by the use of cast-iron cylinders and pistons will very likely be more than offset by the saving in weight of lubricating oil. When it comes to the question of aeroplanes for military use it is of the greatest importance that the passengers and vital parts of the machine be protected as far as possible by armor plate. It is impracticable to use armor plate of sufficient thickness to withstand all kinds of shell fire on account of the weight. On the other hand, however, it is possible to secure some remarkably satisfactory results with very thin plate.

Nitro-starch as an Explosive. S. S. SADTLER. (*Metallurgical and Chemical Engineering,* vol. xvi, No. 7, p. 361, April 1, 1917.)—The application of high explosives to mining and general commercial purposes may be said to date from the discovery of Nobel that nitroglycerin could be absorbed in kieselguhr and then handled with a sufficient degree of safety to warrant its use. The product was called dynamite, but this name now applies broadly not only to nitroglycerin absorbed by other inert materials, like sawdust, mica-powder, etc., and other mixtures as well, but also it applies to various high explosives containing no nitroglycerin. At present there are an indefinite number of chemical mixtures aiming to meet the different working conditions. By the solution of gun-cotton or nitrocellulose in nitroglycerin (in which it readily dissolves, forming a jelly-like mass) we obtain blasting gelatine and gelatine dynamites and mixtures of these with other ingredients. Gun-cotton (or the higher cellulose nitrate) has not been found applicable by itself for the field of commercial blasting and mining explosives, except for submarine blasting, where the compressed gun-cotton finds a use, as it is too bulky in comparison to its weight for other work.

An earnest effort had been made for some time to find a satisfactory substitute for nitroglycerin dynamite, but without success until recently, when great improvements were made in the manufacture of nitro-starch and a suitable container found for its use. Starch, which has an analogous chemical composition

to cellulose and forms corresponding nitrate esters, was early suggested as the basis of a high explosive, having all the advantages of cotton without its bulk or higher cost. For blasting, this material has great many advantages. It cannot be exploded except by exploding a cap in contact with it, it gives off no bad fumes, is non-freezing, and appears to have good stability, a quantity stored for ten months showing no deterioration. One of the chief points of merit in the use of nitro-starch is its cost. As there is no special difficulty in its manufacture, it can readily be seen that, being made from a base costing 2⅛ to 2¼ cents a pound, as compared with glycerine at 30 to 60 cents a pound, or cellulose rising to 10 cents, there is great economy in its use. Quite apart from the cost of bases, but for reasons of simplicity of handling and time of nitration, it promises to be more easily and economically manufactured than nitrocellulose.

Explosions in Oxygen Tanks. ANON. (*Metallurgical and Chemical Engineering*, vol. xvi, No. 7, p. 402, April 1, 1917.)—The attention of the Bureau of Mines has recently been directed to a series of explosions of oxygen made by the electrolytic process in which life has been lost as a result of hydrogen being mixed with the oxygen. It has been found that this is due to improper design in the manufacturing apparatus (*i.e.*, to the cells and electrical connections); to insufficient safeguards connected with the electric apparatus, the polarity suddenly and unexpectedly shifting; to the manufacture of oxygen without frequent analyses, and to incompetent and ignorant attendants. Unfortunately certain makers of oxygen-building apparatus have advertised that any laborer can take care of their apparatus. It is believed that the manufacture of electrolytic oxygen can be carried on in a manner to make it perfectly safe. In fact, there must be over nine per cent. of hydrogen with the oxygen to make an explosive mixture. Nevertheless, certain tanks from one batch caused three widely-separated explosions in California, killing seven men in all, and an analysis of gas from a tank filled at the same time showed that it contained over 50 per cent. of hydrogen.

Census of Mining Engineers and Metallurgists in the United States. VAN H. MANNING. (*Circular letter, U. S. Bureau of Mines*, April 5, 1917.)—The Bureau of Mines, in coöperation with the American Institute of Mining Engineers and the American Chemical Society, has undertaken a census of mining engineers, metallurgists, and chemists with a view of ascertaining the qualifications of each and the line of work in which each can be of the most service to the country in time of emergency. The classification will embrace 27 specific groups of industrial chemists, 16 groups of engineering specialists, and 15 groups in the metal-

lurgical field. By such minute classification the Bureau will be in a position to furnish on short notice the names of specialists for service under the classification, so that in case of necessity these technical men can be available to industrial plants where they would be of most assistance to the country. European experience has shown that nothing is more important in time of national emergency than a knowledge of the qualifications and experience of expert technical men.

Industrial Value of Metallography. ANON. (*The Iron Trade Review*, vol. ix, No. 12, p. 673, March 22, 1917.)—Thirty years ago metallography as a science was almost unknown, and only within the last twenty years has it received serious consideration by manufacturers and consumers as a valuable means of metal testing. The development of metallography in the early years of its history was slow, but the advances in the past five years have probably exceeded all those previously made. At the present day metallography is taught in almost all technical and engineering schools of university grade, and methods of metallographic testing find wide use in the metallography of iron and steel and the non-ferrous alloys as well.

Metals and alloys owe their industrial importance to their physical properties in a large measure, and it is in testing and determining these physical properties that the methods of metallography have come to be almost indispensable. For instance, the great advances in the production of high-quality rail steel could scarcely have been brought about without the aid of the new science. The physical properties of metals and alloys are dependent upon their proximate structural compositions rather than upon their ultimate chemical compositions, and it is in revealing the former that the value of metallographic testing lies. The methods of chemistry furnish information of the utmost value, but they do not make possible much knowledge concerning the structure and physical constitution of substances.

Noiseless Cotton Gear-wheels. ANON. (*Scientific American*, vol. cxvi, No. 12, March 24, 1917.)—Steel gears and pinions are among the noisiest creations of man. By providing steel gear trains with cotton-ball pinions, the noise is eliminated, much to the comfort and health of the operatives, and greater efficiency and increased production secured. These new pinions are remarkable for strength, elasticity, and toughness. They will outwear iron or brass and are proof against damage by water, oil, dryness, or temperature changes. They have been adapted to all kinds of machines, from automobiles to turbine engines, and because of their durability and noiseless operation they are applicable to numerous types of machine tools. They likewise find a wide use in spinning and weaving machinery.

Only the highest quality of cotton is used in the manufacture of these gears, and it must be thoroughly cleaned. It is received at the factory in the usual rolls as it comes from the roving frames. These are rewound on cylinders and compressed by hydraulic pressure into " blanks " for the gear-cutting machines. These blanks are usually formed with an outer covering of steel, no metal bushing being used in the bore. The cotton filler is compressed under hydraulic pressure of several tons per square inch of side surface, and held in compression by the steel shrouds or side plates by threaded studs. In the large gears having special hubs, economy of manufacture requires the use of a metal centre and a separate cotton rim. The blanks impregnated with oil are cut on the usual gear shapers or with rotary cutters.

Making Milk Bottles of Paper. ANON. (*Scientific American*, vol. cxvi, No. 11, p. 275, March 17, 1917.)—A rather general movement has taken place toward the abolishment of the well-nigh universally used glass milk bottle. When, many years ago, the glass bottle supplanted the customary can-and-dipper method of serving milk, it was looked upon, and doubtless was, an important step in improving sanitary conditions of milk supply. Now doctors and health experts condemn the glass bottle as a pernicious germ carrier. They are demanding that destructible bottles be used for the distribution of milk in the homes of dairy patrons, so that they cannot be returned to the dairy to be refilled and sent out another time, laden perhaps with germs picked up in the first home.

In that connection it is interesting to note that a new machine has just been perfected by a western inventor that will manufacture paper milk bottles at the rate of 5000 an hour. It is a radical departure from previous contrivances in that it manufactures the new bottles from wood pulp rather from a finished paper, as is done in the case of practically all the containers on the market to-day. This feature insures a very low cost of the product, well within the reach of the average milk dealer. It is claimed that the new paper bottle is cheaper in the long run than the common glass bottle.

The process of manufacture is simple. A steel core is dipped into a tank of raw pulp, and by means of four clamps the pulp is pressed around the core, forming a seamless body, much as a sculptor presses soft clay into shape with his hands. During this operation the bottle revolves three complete times, the clamps pressing at every one-third turn. Thus the paper and the bottle are formed in one and the same operation. The bottle next passes through a drier and over a stencil cut which prints on it the name of the dealer, the capacity of the bottle, etc. It is then removed from the core by a steel hand and deposited on a belt conveyor, which delivers it to a machine which crimps on the bottom and top. The bottle is then given a paraffin bath that renders it impervious to liquid or acid, and is

automatically packed in dust-proof cartons for delivery to the dealer. The operation is continuous, and it takes about eight minutes to convert the raw pulp into the completed milk bottle. Less than half an ounce of wood pulp is required to make one of the new sanitary bottles, and one ton of pulp will produce 60,000 containers. Three men only are required to operate the machine, and from beginning to end the bottle is handled only by steel fingers, so that the apparatus meets all sanitary requirements.

Plastic Cements. J. B. BARNITT. (*Metallurgical and Chemical Engineering*, vol. xvi, No. 6, p. 321, March 15, 1917.)—A working knowledge of the correct mixtures and proper application of plastic cements is deemed so essential to successful chemical engineering operations that an effort has been made to collect and classify a few of the more valuable formulas and suggestions gained both from experience and current literature.

It is to be understood that plastic cements cover that range of adhesives which are used to secure joints and connections between like and unlike material of more or less permanent character. Physically speaking, plastic cements consist of a vehicle in which are suspended or dissolved solids of such nature that they are resistant to the gases and liquids coming in contact with them. In some cases the constituents of the cement react with each other or with the surfaces to which they are applied, thus forming a more strongly adhering mass.

One of the principal precautions to be observed in the application of a cement is the condition of the material to be joined. All connections should be properly fitted together with flanges or exposed flat surfaces as nearly coincident as possible. The cement should never be depended upon to do what the pipes or other portions of the apparatus should do; its function is to cement or seal, and nothing more. In most cases one part of the fitting should overlap the other so as to make a small amount of the cement effective. Cement for a joint of this type should be of such a nature that it may be quickly applied; that is, effective while in place and easily removed when desired. An excess of cement should always be avoided to prevent shrinkage cracks and leaks.

The general methods of plastic cement application are varied to suit special cases, as follows: (*a*) Heating the composition to make it plastic. (*b*) Heat applied to the surface to be cemented. (*c*) Application of the cement with water or a volatile solvent, depending upon the evaporation of the solvent for drying or setting. (*d*) Moistening the surfaces to be cemented with water, oil, etc. (the vehicle of the cement itself. (*e*) Application of the cement in workable condition, setting taking place by chemical reaction, hydration, or oxidation. The application of the following materials as plastic cements is noted: (1) plaster-of-Paris; (2) hydraulic cement; (3) clay; (4) lime; (5 asphalt or pitch; (6) rosin; (7) rubber (8)

linseed oil; (9) casein and albumen; (10) silicate of soda and oxychloride cement; (11) flour and starch; ((12) miscellaneous materials.

Authoritative Data on the Properties of Metals and Alloys. S. W. STRATTON. (*Circular letter, U. S. Bureau of Standards,* March 24, 1917.)—The Bureau is undertaking to compile the present state of knowledge and practice concerning the numerical values used by engineers and others for the properties of metals and alloys, with a view to making generally available the most acceptable values of these constants and also as a basis for further experimental investigation. A form sheet is furnished containing the various items required. These cover the mechanical, thermal, electrical, and optical properties of value to the investigator and engineer. A sheet of instructions for compiling the table with an illustrative filled-out form for commercial electrolytic copper is included. This contains a list of the alloys on which data are particularly desired.

Closely-drilled Gas Fields Short-lived. ANON. (*U. S. Geological Survey, Press Bulletin* No. 313, March, 1917.)—One of the most important problems confronting the gas-producing industry is that of determining the smallest number of wells capable of removing most economically all the gas under a given tract of land. So many complex factors enter into this problem that few systematic attempts have been made to solve it, and gas operators have in general been content to accept rough estimates of the number of wells that should be drilled per unit of area. In some localities it is held that only one well should be drilled to each 800 acres; in others it is customary to drill a well in each 20 or 40 acres. With present knowledge the number to be drilled must be to some extent a matter of opinion, and it is very doubtful whether any limit can be fixed that will be applicable to all fields.

Those who are familiar with the gas industry have long realized that a closely-drilled field is short-lived, and that in most pools the later wells are less likely to be profitable than the earlier ones. Few operators, however, have attempted to analyze the reasons for these conditions, and most of the business men and others who are occasionally induced to take a " flyer " in gas producing seem to be ignorant of the existence of them. Hence, in many eastern gas fields there are more wells than are necessary or profitable, and in some fields the wells are crowded so closely that many of them have never produced enough gas to pay for themselves.

A study of the available records of rock pressure and flow of wells in the Cleveland field indicates that the decline of rock pressure in the older wells is a valuable criterion in controlling new development. Probably in most fields the wells that are brought in after the general pressure has declined to one-third of its original amount are

unprofitable, and in many fields this point may be reached when the pressure has declined only one-half.

The geology of the Cleveland field in relation to the accumulation of the gas has recently been investigated by the United States Geological Survey, Department of the Interior, and is discussed in Bulletin 661-A, entitled "The Cleveland Gas Field, Cuyahoga County, Ohio, with a Study of Rock Pressure," by G. Sherburne Rogers. A copy of this report may be obtained on application to the Director of the Geological Survey, Washington, D. C.

Useful Minerals of the United States. ANON. (*U. S. Geological Survey Press Bulletin*, No. 312, March, 1917.)—A new edition of the popular work entitled, "Useful Minerals of the United States," is being published by the United States Geological Survey, Department of the Interior, as Bulletin 624. It is a revised, enlarged, and up-to-date edition of a bulletin that was issued about two years ago. A large edition of that bulletin was published, but it soon became exhausted, and several thousand applications for it were received after the edition printed had been distributed.

Bulletin 624 notes the enormous increase in development, production, and value of the useful minerals of the country during the last 25 years and many of the changes and discoveries that have taken place in the mineral industry. It aims also to supply the rapidly growing demand for information regarding our mineral resources and the special demand occasioned by the European War.

Besides giving several thousand new localities of mineral deposits and adding more than 160 new mineral names to the glossary, the new bulletin furnishes considerable additional information concerning certain minerals, especially the uranium and vanadium minerals found in the high plateau region of the West. The present bulletin, like the earlier work, gives concisely, by states and counties, the location of the principal deposits of useful minerals and includes a glossary showing the composition and character of each mineral and the location of its principal deposits. It gives also the principal uses of each mineral, which were not stated in the first edition. As a mineral directory, it promises to be of service to scientific bureaus and educational institutions that prepare replies to the numerous inquiries of the general public on subjects connected with what may be called commercial mineralogy, as well as to the prospector, miner, manufacturer, and business man and the student of economic conditions.

Flexible Gear for Ship Propulsion. L. R. EMMET. (*General Electric Review*, vol. xx, No. 3, p. 238, March, 1917.)—Perhaps the most serious obstacle to the adaptation of reduction gears to marine turbines has been the difficulty of securing the accurate contact conditions between the teeth of the gears essential to efficient transmission, durability, and freedom from breakdown, and much study

and costly experiment have been expended in the effort to insure this end. An ingenious and most attractive method, in its simplicity of overcoming contact difficulties encountered in the wide-face high-speed gears employed with ship-propulsion turbines, has been devised by Karl Alquist, of the General Electric Company. To secure quiet running, helical gears are ordinarily employed for this service. These are mounted on the shaft in pairs with equal and opposite helical angles for the purpose of neutralizing the axial component of the tooth pressure, and are kinematically equivalent to the time-honored " herring-bone " gears used in rolling-mill practice.

When the gears are solid and inflexible, there is always a tendency for the stress at the loaded end of the pinion to be increased by torsional deflection. There is also a tendency to inequality of stress upon the tooth surface from lateral deflection. These deflection troubles are overcome in the Alquist gear by making the relatively large driven gear in several sections, solidly bolted together at the hub but separated from each other at all other points, so that if any undue pressure tends to occur at the tooth-surface of a section a slight deflection of the thin and elastic section immediately acts to maintain the pressure at its normal value. To insure that these sections shall be in proper relation to each other, the gear blanks are provided with a contact surface at the periphery as well as at the hubs, assembled and cut as a solid gear. After the teeth have been formed the contact surface is cut away, leaving the teeth in as perfect alignment as if cut from a solid blank.

Many sets of this gearing have been built and experimented with exhaustively under a variety of conditions, and by these experiments certain standards of practicability have been established and extensive commercial developments undertaken. Gearing of this character has been applied to about 72 sets of turbo-electric generators of various types and contracts have been closed for the machinery for the propulsion of seventy ships aggregating 215,000 horsepower. Some of these electric generating sets have been in service one and one-half years, and about seven of the ship sets are in service, some of them having made many long voyages. Among these are the high-pressure cruising units of the battleship *Nevada*, which have given very satisfactory results. Among the ship equipments not yet completed are included the propelling machinery for *Destroyer No. 69*, built at Mare Island, and the new propelling machinery for scout cruiser *Salem*. In all this practical experience no case of trouble with the gearing has developed and no appreciable deterioration of gears has been observed.

Vacuous Arc Lamps. ANON. (*Electrical World*, vol. lxix, No. 6, p. 270, February 10, 1917.)—An arc lamp operating in a vacuum chamber, in which the electrodes are fixed and non-distintegrating, constitutes patent No. 1,208,597 to George M. J. Mackay, of Schenectady, N. Y. The essential condition of operation appears to be

that one electrode be incandescent, and for this reason two conductors are led into the top of the envelope, whereas only one lead is provided for the anode. The device comprises an envelope consisting of glass, such as low-expansion or sodium-magnesium borosilicate glass. The cathode consists of highly refractive material having a melting-point exceeding at least 2000° C., such, for example, as tungsten, tantalum, carbon, or the like. The anode consists of conductive material—for example, tungsten, carbon, or other solids—but in some cases a liquid such as mercury may be used.

The globe is first evacuated and then filled with a suitable gas at considerable pressure. Monatomic gases of the argon group, also nitrogen and carbon monoxide, may be used. The gaseous pressure will more usually approach atmospheric pressure in order of magnitude. In a device used for rectifying alternating current at low voltages, argon at a pressure of about 5 to 12 centimetres of mercury is found suitable. With an envelope containing a filling of nitrogen, phosphorus pentoxide is preferred for absorbing water vapor and other gaseous impurities. In devices filled with a monatomic gas (such as argon, neon, krypton, xenon, or helium), calcium magnesium, or one of the related metals is preferable. By the use of a gas-absorbing chemical agent, the potential drop or loss is reduced to one-half, or even less.

To give specific illustrations, an incandescent cathode arc, carrying about 6 ampères, when filled with argon purified by ordinary methods, has an arc drop of about 30 to 40 volts. When the envelope contains a small quantity of phosphorous pentoxide, as above described, the arc drop is reduced to about 10 volts. Similarly a 6-ampère neon tube containing, at a pressure of about half an atmosphere, neon gas purified by the usual methods, has an arc drop of about 50 volts. The same tube, when provided with metallic calcium acting to purify the gas *in situ* in the manner above described, has an arc drop of about 20 volts.

Printing Plates from Phenol Resin Compounds. L. V. REDMAN and W. F. P. BROCK. (*Journal of Industrial and Engineering Chemistry*, vol. 9, No. 4, p. 388, April, 1917.)—The growth of syndicate work in illustrated advertising, comic supplement and "filler" for our 30,000 American newspapers has created a need for material that will lend itself to the rapid production of plates in manifold. The plate requires to be produced rapidly and inexpensively, and must be of such a quality as will print clearly on the cheap sheet used by daily papers. For this purpose celluloid compounds have been used with some success. Shellac has also been tried, and vulcanized rubber has been suggested, but neither commercially applied.

A satisfactory mould in every way can be made from the phenol moulding compounds. A sheet of the plastic phenol moulding compound is placed on a hot plate until the sheet has

heated through and becomes soft and pliable. The original zinc etching is then placed on the warm plastic sheet and pressed. The pressure is raised gradually to about 2000 pounds per square inch. The mould formed in this way has generally a thickness of 1/16 to 1/32 of an inch. After cooling the hard plastic sheet has on its face a negative of the original zinc etching. On this negative mould another plastic sheet is laid and a positive printing plate is produced. As the plastic sheet and mould would naturally weld together in the hot press, various methods are used to prevent the plate sticking to the negative. A layer of oiled paper, thin metal, talc dust, etc., between the mould and cast have proved satisfactory. The ordinary newspaper cut is made with a 100-mesh screen, but it has been found possible to reproduce plates made with a screen of 150-mesh. The weight of the moulded plate is one-sixth the weight of the corresponding zinc etchings, and contributes a saving in shipping cost equal to the original cost of the plate.

Electric Activity in Ore Deposits. ANON. (*U. S. Geological Survey Press Bulletin*, No. 315 April, 1917.)—Accomplisments in electric science have far surpassed anything that men would have dared to predict in the early days of its development, yet certain prophecies in regard to it have remained unfulfilled. Among these are the suggestions of some geologists that electric phenomena might play an important part in the formation of ore deposits and that electric methods might be utilized in prospecting for ore bodies. Both these suggestions, in the light of the growing knowledge of ore deposits and of electricity, appear to be illusions. It is now clear that the great causes of ore deposition are not electric in the ordinary sense and that the electric currents generated in ore deposits are far too small to aid a prospector in discovering ore by their influence on a galvanometer or other electric apparatus held in his hands.

If, however, electricity is denied a leading part in the formation of ore deposits, its action cannot be excluded entirely. It is well known that many chemical reactions are capable of developing measurable electric currents, and it should therefore be expected that in places where chemical action is in progress in ore deposits to-day electric activity should also be detectable. This has indeed been shown to be the case by several experimenters, and minature batteries can be formed with water for the battery fluid and certain metallic minerals common in ore deposits as the poles. Bulletin 540, entitled "Electric Activity in Ore Deposits," by Roger C. Wells, recently issued by the United States Geological Survey, records a series of careful measurements of the electric potentials developed when various metallic minerals common in ore deposits are in contact with water or with solutions of various salts. Mr. Wells concludes that the character of

the solutions has fully as great an influence on the electric activity developed as the nature of the metallic minerals, and that in general acid and oxidizing solutions give the highest potentials and alkaline and reducing solutions the lowest. Economic geologists have long recognized that the solutions in the upper oxidized portion of many ore deposits are acid and oxidizing, while farther down they become neutral or alkaline. Whether such variations and the electric differences dependent upon them are sufficient to cause an appreciable electric current to flow from the upper part of an ore deposit to a lower part or *vice versa* is still an open question. Surely such action, if it exists, is of relatively minor importance in controlling ore deposition, the main factor being the actual movement of metal-bearing solutions from one place to another. Measurements of electric potential can, however, be quickly and easily made and may prove very useful in indicating the direction and intensity of the chemical reactions of which they are one expression.

The Fixation of Nitrogen. J. E. BUCHER. (*The Journal of Industrial and Engineering Chemistry*, vol. 9, No. 3, p. 233, March, 1917.)—A process for the fixation of nitrogen has been developed, differing primarily from all those now in commercial use in fixing nitrogen, in the form of alkali cyanides instead of in the form of oxides of nitrogen, calcium cyanimide, nitrides, or ammonia. It is further characterized by operating at very moderate temperatures, such as 900 to 950° C., so that it is not dependent upon cheap electric power, and, because of this moderate temperature, it can be operated in iron retorts. It is of the utmost simplicity, uses iron, which is the cheapest metallic catalyzer, and does not require pure materials, such as nitrogen, but can use air or producer gas just as well. It requires no special apparatus and can be operated at once with what can be found in practically every manufacturing community. It does not require skilled labor to operate it, and it is preëminently a method that can be installed quickly in an emergency for the preparation of cyanides, ammonia, and nitric acid.

The process is based upon the property that nitrogen will combine with an alkali and carbon in the presence of iron as a catalyst and produce cyanides. That is, by heating a mixture of carbonate of soda and powdered coke in a furnace and passing air over the mixture, cyanide of soda is produced with the iron uncombined. No electric power is needed, no heavy outlay, no costly materials; the whole process can be carried out anywhere at apparently very low cost. By leading waste gas (carbon dioxide) from a furnace into a solution of cyanide of soda, urea is produced, a compound which bids fair to yield remarkable results as a fertilizer.

The cyanide of soda under influence of an electric current

separates into metallic sodium, for which there is a large demand in chemical industry, and cyanogen. The cyanogen is rapidly absorbed in hydrochloric acid and becomes oxamide. This contains nearly one-third nitrogen in combination and is nearly insoluble, so that it would not be washed away from the soil by rains, and it also should make an ideal fertilizer. The use of urea or oxamide as fertilizer has never been considered in the past on account of its cost.

Earth, Sand-clay, and Gravel Roads. ANON. (*Bulletin No. 463, U. S. Department of Agriculture.*)—Nearly 2,400,000 miles of the two and a half million miles of public roads in the United States are of earth, sand-clay, or gravel, according to recent statistics gathered by the Office of Public Roads and Rural Engineering of the U. S. Department of Agriculture. Roads of these materials are therefore of predominant importance in most communities of the country and probably will remain so for many years. For this reason the Office of Public Roads and Rural Engineering has issued as Department of Agriculture Bulletin No. 463 a comprehensive discussion of the materials, methods of construction, and maintenance for the three types.

Most roads are located originally as earth roads, the bulletin points out. In such location work the fact that the road eventually may develop into an important highway should be kept constantly in mind and routes should be chosen which will not have to be radically changed, perhaps at great expense, at some future time. The tendency in many rural communities to locate all new roads along land lines has been responsible for much waste. The importance of grade, drainage, and width of roads, as well as the materials of which they are built, is emphasized in the publication, and the machinery and tools used in constructing roads of the different materials are described. The necessity for adequate maintenance is brought out, and in this connection directions are given for the making and use of road drags. Typical specifications for the construction of roads from earth, sand-clay, and gravel are included in an appendix.

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